PB84-141191

Responses of Airborne Biota to Microwave Transmission from Satellite Power System (SPS)

Little (Arthur D.), Inc., Cambridge, MA

Prepared for

Health Effects Research Lab.
Reserach Triangle Park, NC

Jan 84

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-141191

EPA-600/1-84-001
January 1984

RESPONSES OF AIRBORNE BIOTA TO MICROWAVE TRANSMISSION FROM SATELLITE POWER SYSTEM (SPS)

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Contract Number:
68-02-3278

Under Interagency Agreement With
the Department of Energy
EPA-78-R-X-03771-1
DE-AI01-79ER10060

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INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/1-84-001

2.

3. RECIPIENT'S ACCESSION NO. PB84 141191

4. TITLE AND SUBTITLE
RESPONSES OF AIRBORNE BIOTA TO MICROWAVE TRANSMISSION
FROM SATELLITE POWER SYSTEM (SPS)

5. REPORT DATE January 1984

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) Arthur D. Little, Inc.

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Arthur D. Little, Inc.
Cambridge, MA 02140

10. PROGRAM ELEMENT NO. CCGF1A

11. CONTRACT/GRANT NO. 68-02-3278

12. SPONSORING AGENCY NAME AND ADDRESS
Office of Research & Development
Health Effects Research Laboratory
US Environmental Protection Agency
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE EPA-600/11

15. SUPPLEMENTARY NOTES
Also authored by: Boston University & Manomet Bird Observatory

16. ABSTRACT

The goal of this program is to determine whether microwave irradiation adversely alters a wide-range of complex avian behavior modes that are essential to their survival. Effects of microwaves (2.45 GHz) have been studied extensively in mammalian species, e.g., rats, mice, rabbits and monkeys, but very little information is available for birds. Avian species, generally, have higher rates of metabolism (especially during flight), stand on two feet and have an elongated neck that increases the amount of isolation between the head and thorax. All of these anatomical features can be expected to increase the susceptibility of birds to hyperthermia, vestibular and nueromuscular dysfunction as well as more subtle altered behaviors, e.g., inappropriate migratory behavior due to interference with normal astronomical or geomagnetic clues.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT

19. SECURITY CLASS *(This Report)*

20. SECURITY CLASS *(This page)*

21. NO. OF PAGES 444

22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, nonionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory participates in the development and revision of air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is primarily responsible for providing the health basis for nonionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

This study is intended to establish whether the transmission of energy from a satellite power system using microwave radiation as the satellite to Earth link will affect critical processes in the life cycle of birds. The work was performed by Arthur D. Little, Inc. as prime contractor and managed by the Environmental Protection Agency with funding provided by the Department of Energy under an interagency agreement.

F.G. Hueter, Ph.D.
Director
Health Effects Research Laboratory

ABSTRACT

Studies were conducted to determine whether microwave irradiation (2.45 GHz) as would be produced by the proposed Satellite Power System would constitute a hazard to exposed avian species or influence their survival.

Results showed that birds exposed to microwave fields, e.g., at the proposed rectenna site are able to respond to the field by either avoidance or attraction depending upon the power density of the field. Ambient conditions such as temperature, humidity and wind speed are also likely to be important factors in determining the nature and magnitude of the response. Birds that are exposed to microwave irradiation were found to exhibit well-defined thermoregulatory behavior patterns as the level of exposure is increased. Based on results comparing responses to House Finches and Blue Jays at 25 mW/cm^2, the smaller bird appears to exhibit less intense thermoregulatory stress responses than do larger birds. Thus, avian species entering the SPS whose body mass are considerably larger than the Blue Jays (~85g) used in this study, could be even more susceptible to thermoregulatory stress. At low ambient temperatures, e.g., 7 to 13°C, birds at rest tolerate relatively large levels of microwave exposure. Based on experiments with two Dark-Eyed Juncos, these birds were able to survive microwave irradiation at 130 MW/cm^3 for 20 minutes of continuous exposure whereas after 7 minutes two other birds died at 160 mW/cm^3 and two of four birds (50%) survived 150 mW/cm^2 exposures. The orientation of a bird's body with respect to the E field vector of the microwave field is important in determining the magnitude of thermal stress. Both House Finches and Blue Jays experience significantly greater elevation in cloacal temperature when the longitudinal axis of the body was oriented parallel to the E vector than when the birds were oriented perpendicular to the E vector. Birds exposed to microwave irradiation up to 25 mW/cm^2 showed no notable differences in foraging (feeding) efficiency from control birds during acute (2, 20, 200 minutes), 7 day continuous and 4 week continuous exposures.

Microwave exposure did not change the quality of nocturnal activity, or "Zugenruhe," exhibited by birds (White-throated Sparrows), exposed and observed in microwave-transparent Emlem orientation cages. Microwaves also did not affect the ability of birds to maintain oriented movements. Approximately one third of all birds tested maintained directional behavior, regardless of cloud-cover or other environmental variables. Likewise, the strength of the orientation of these birds was not affected by microwaves. Also, microwaves did not affect the specific directional preferences of non-randomly orienting birds grouped under various cloudover conditions. The non-treated birds, however, showed their movements to be non-randomly distributed on nights with clear skies and on all nights combined. The same distributions of microwave treated birds were found to be random. Therefore, while the mean angles, or preferred directions were same, the microwave treated birds showed a greater dispersion of chosen directions around the mean. We conclude that although there was no significant change in directional preference by birds exposed to microwaves at the power densities projected for use by the SPS, the increased dispersion of those treated birds represents an altered response to microwave which can be considered as potentially hazardous to migratory birds and therefore deserves further study.

The effects of microwave irradiation on birds in flight were studied by exposing Budgerigars in a wind tunnel while flying in a 37 Km/h wind. Air temperature and humidity markedly influenced the level of thermoregulatory behavior exhibited by all birds as well as the ability of birds to sustain flight. At exposures of 50 mW/cm^2 and air temperatures above 26°C, compared to control (nonirradiated) birds, microwave exposed birds show greater levels of thermoregulatory behavior, a lower ability to maintain flight, higher body temperatures, and require longer periods of time for recovery when flights are terminated.

Birds exposed continuously to microwave radiation (25 mW/cm^2) were able to breed successfully. Although the pairs of Zebra Finches that were irradiated produced fewer total numbers of eggs and fewer fertile eggs, there was no significant difference in the number of fledglings produced by the irradiated and control pairs of birds. Based on an absence of altered numbers of fledglings produced by irradiated pairs of birds during mating, the data show that microwaves at rectenna sites should not impair species survival as a result of disruption of normal reproductive behavior.

Results of studies in which Coturnix Quail eggs were irradiated at 25 mW/cm^2, twice daily for 30 minutes during the normal (17 day) period of incubation, reveal that microwave irradiation at the SPS rectenna would not be expected to reduce egg hatchability in the field.

Microwave irradiation may have a subtle effect on the behavior of birds within a dominance hierarchy but the effect is probably not strong enough to alter the absolute position of birds within the hierarchy and influence survival of the flock.

To determine whether exposure of birds to microwave irradiation alters molt, (the cyclic loss and regrowth of feathers), House Finches were continuously exposed to microwave irradiation at levels of 0, 1, 10 or 25 mW/cm^2 for the 110 to 150 day molting period. All birds completed the 1 and 10 mW/cm^2. The rate was slower for the last half of the molt for the two birds receiving 25 mW/cm^2. Since these latter birds were well into the molting process at the time they were captured and included in the study, it is not possible to determine whether the delayed rate of molting was related to microwave exposure or to altered molting due to changes in environment (e.g., captivity). At the end of the exposure period, individual birds receiving 25 mW/cm^2 were examined for altered behavior, as well as a variety of different somatic and visceral reflexes and then killed. At necropsy, major organs were examined and sections prepared for histologic examination. No notable differences were observed in the incidence and severity of lesions between control and microwave treated birds.

This report was submitted in fulfillment of Contract No. 68-02-3278 by Arthur D Little, Inc. The contract was managed by the Environmental Protection Agency with funding provided by the Department of Energy under Interagency Agreement EPA-78-R-X-03771-1, DE-AI01-79ER10060. The report covers the period from October 1979 to March 1983.

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1. INTRODUCTION

1.1 Background

Birds (Aves) are an important group to consider in any assessment of the environmental impact of the Satellite Power System (SPS) since as a class, they are ubiquitous and are commonly found in any area likely to be selected as a rectenna site. Their nearly absolute freedom of movement means that no practical method exists to prevent their access to the rectenna either during flights across the area or when landing to feed, nest or rest.

In the wild, birds exhibit a wide range of complex interrelated tasks and behavior modes that are essential to their survival that may be altered by microwave exposure. Due to the rapid proliferation of military and commercial microwave emitters since World War II, considerable research has been conducted on the biological effects of microwaves. Unfortunately, very little of the accumulated literature has applicability to a study of the potential hazards for avian species exposed at a rectenna site to the far field of linearly polarized, continuous wave, 2.45 GHz microwaves.

The dose of energy that an animal will actually absorb when it is irradiated by a microwave field of a given power density is strongly dependent upon the microwave frequency, the physical environment, the animal's size and the animal's orientation to the electric (E) vector of the microwave field (Gandhi 1980). In many studies, the physical environment is inadequately described, the animal's orientation is ignored and insufficient data are presented to permit the calculation of the absorbed dosage.

The majority of nonhuman studies are conducted with mammals: rats, mice, rabbits and monkeys. Birds have higher rates of metabolism than do mammals, stand on two feet and have elongated necks; factors that would be expected to increase the susceptibility of these animals over commonly used mammalian species to hyperthermia and vestibular and neuromuscular dysfunctions due to microwave exposure. Bird embryos that are exposed during incubation should be more vulnerable to hyperthermia than are mammalian embryos because the embryonic bird is obviously not shielded by its parents when the parents are absent from the nest.

Some recent research papers have discussed the biological effects of 2.45 GHz microwaves on birds and on bird-sized mammals. Power densities of less than 10 mW/cm^2 have been shown to induce peripheral vasodilation in squirrel monkeys (*Saimuri sciureus*) (Adair and Adams 1980), and affect thermoregulatory (Stern 1979) and learned behavior in rats (Thomas *et al*., 1975). Thirty-minute exposures of 20 to 50 mW/cm^2 produced histopathologic changes in the testes and epididymides of rats (Dukovic *et al*., 1979). At an ambient temperature of 24°C (RH = 50%), absorbed dosages above 27 mW/g increased heat dissipation rates in mice (Ho and McManaway 1977). An adsorbed dose rate of 197.4 mW/g for 5 min (Rugh and McManaway 1976) or a 30-minute exposure of 3.3 cal/min (Rugh *et al*., 1975) was teratogenic to embryonic mice. Power densities of 20 mW/cm^2, and above, induce elevated colonic temperature and elevated corticosteriod levels in rats (Lotz and Michaelson 1978).

Chickens and Japanese Quail (*Coturnix coturnix japonica*) have been the primary avian subjects used in microwave studies. Hens irradiated by 1 mW/cm^2

(2.435 GHz) showed a reduced egg production (Krueger et al., 1975). The eggs laid by the irradiated hens did not show reduced hatchability. Japanese Quail eggs irradiated by 246 mW/cm^2 (120 s) and 1020 mW/cm^2 (30 s) showed decreased hatchability whereas eggs irradiated for 240 s by 51 mW/cm^2 did not (Hills et al., 1974). Quail eggs irradiated by 30 mW/cm^2 (2.450 GHz, CW) for 4 hours during each of the first 5 days of incubation, while maintained at temperatures between 35-37°C, did not show decreased hatchability nor did the birds hatched from those eggs demonstrate an increased number of deformities (McRee et al., 1975). Quail eggs continuously irradiated by 5 mW/cm^2 (4.03 W/kg) during the first 12 days of incubation produced hatchlings that weighed 12-17 percent less than controls at 4-5 weeks post hatching (Hamrick et al., 1977).

The microwave effects produced in the above studies suggest that under laboratory conditions, power densities between 10 and 50 mW/cm^2 are likely to alter bird behavior due to thermal effects and may reduce hatchability of irradiated eggs if they are irradiated for longer than 5 minutes and egg temperatures rises above 37°C.

The present avian behavioral study of microwave-induced effects include experiments conducted in both field and laboratory environments. According to our definition, behavior refers to externally observable manifestations of bird activity, and any alterations in this activity may be attributable to the microwave field. Although operant behavior studies may be the more sensitive indicators of behavioral changes, there are serious problems in attempting to apply operant methods to members of wild animal populations. To date, no evidence exists for the success of operant conditioning in wild birds which does not result in a concomitant alteration in "normal responses," i.e., responses typical of those obtained in the wild state.

Avian behaviors may be arbitrarily divided into two subcategories, migratory and non-migratory behavior. Non-migratory behavior includes activities of the bird such as breeding, flocking, feeding, and other individual and social activity. These non-migratory behaviors are assessed by studies such as molt, social interaction, mating, foraging, flight etc. Migratory behavior is assessed by studies of orientation during migratory periods.

For the study a 5600 square foot building was completely renovated by Arthur D. Little, and provided with special electrical, plumbing and other services required for maintaining and exposing birds to a wide range of microwave power densities (2.45 GHz). This dedicated Microwave Irradiation Facility contained five microwave exposure chambers and two replicate control chambers. Microwave energy from two generators with adjustable outputs was used to establish a nominal power density of 25 mW/cm^2 in each of two chambers, and a third generator was used to establish microwave power densities of 0.1, 1.0, and 10 mW/cm^2 in each of the other three chambers, respectively. The site selected was an isolated location to minimize the possibility of accidental exposure of the public to high voltage and microwave radiation.

A requirement for the design of exposure cages (for holding the birds during irradiation) was that it would not perturb the microwave field.

Because of this requirement structural materials used were both microwave transparent and compatible with biological systems.

The facility also contains a wind tunnel and two large flight cages. One of the five exposure chambers was used in conjunction with the wind tunnel and permitted the irradiation of birds to levels ranging between 0 and 50 mW/cm^2. The wind tunnel was an open-jet type with two upstream fans and was mounted on a tilt-frame for adjusting the flow angle of the air stream at wind speeds of 37 Km/min. The two flight cages were designed and built large enough to maintain the bird fitness for flight in the wind tunnel.

A fundamental requirement of the present study was that the exposure conditions of the irradiated birds (2.45 GHz) be well controlled and accurately quantified. In particular, the microwave exposure was limited to irradiation by a plane-wave field of known polarization and power density. Our objective was to establish a microwave power density uniformity of + 0.5 db throughout the test chamber in the absence of any test biota, but including cages and/or other confining and life supporting structures, and to determine indirectly the actual energy absorbed by the bird.

To maintain a simple microwave field, i.e., no standing waves or phase front distortion, the design of the exposure facilities included the following:

-- exposure chambers with anechoic boundaries

- cages and life support equipment constructed of low dielectric constant, low loss-tangent materials

- placement in the radiating far field region of the microwave illuminator and, when necessary, the biota separated sufficiently from each other to prevent one animal from distorting the field experienced by another

Dosimetry by direct measurement of microwave energy actually absorbed by live birds undergoing plane-wave irradiation in an anechoic chamber is not yet practical. These determinations were therefore made by an indirect process which requires that the microwave absorption cross section of the bird be determined as a function of its orientation to the plane-wave front, and that the fraction of time spent in various orientations be determined by observation. The energy absorption rate resulting from exposure to the microwave field may then be computed. Two types of exposures were used in the program. The first involved exposure of birds in their natural habitat; e.g., social interaction and orientation of birds. The second type involved use of chambers to irradiate birds in the laboratory, e.g., aversion/attraction, molt, foraging, nesting and reproduction.

The mechanisms and loci of avian responses to microwave radiation at levels less than those producing rapid generalized hyperthermia are difficult to study. In this study, knowledge of mechanisms is secondary to the primary goal of a determination of exposure-correlated responses. We have therefore employed a set of behavioral indicators. Behavior, especially complex behavior, represents the observable endpoint of a number of physiological conditions and interrelated external stimuli.

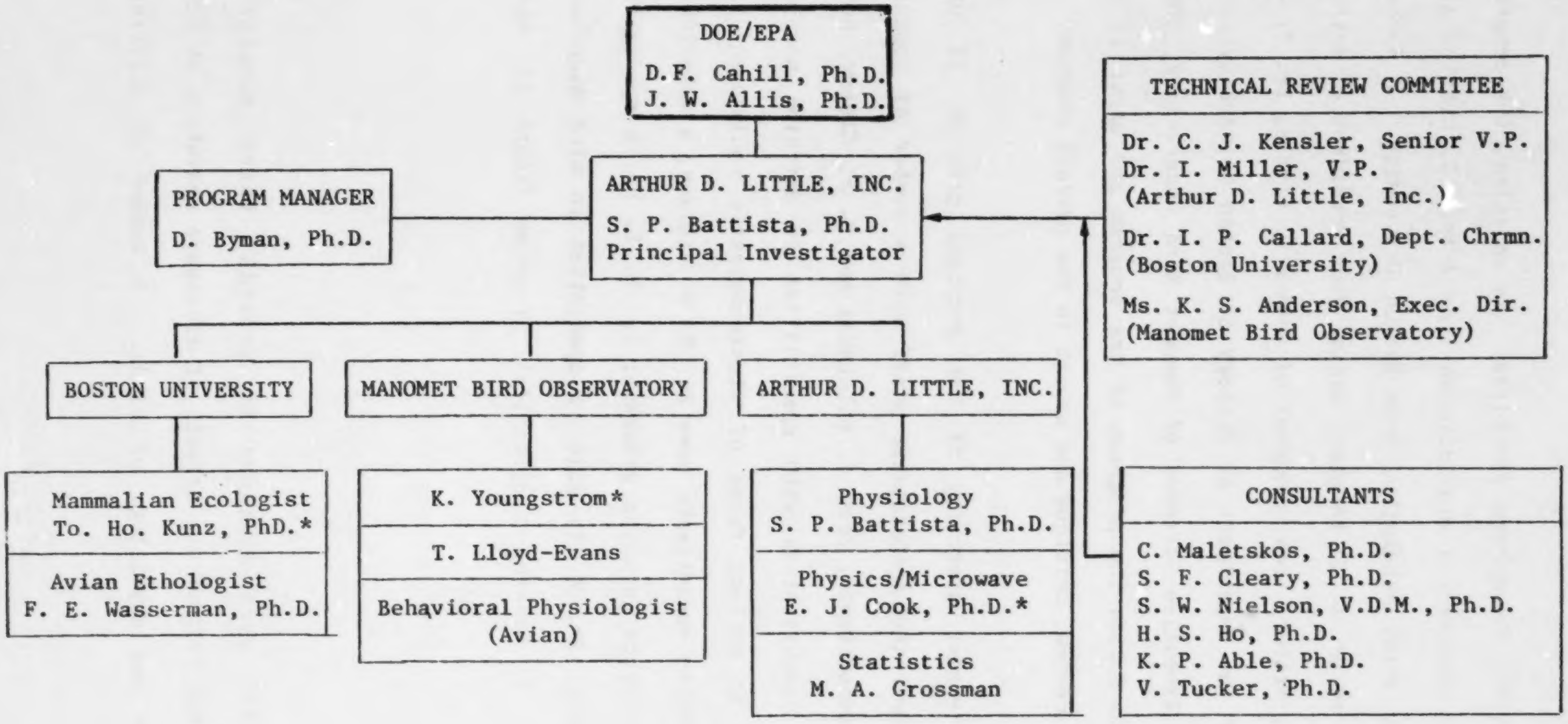
Although the use of behavioral analysis as a sensitive indicator of altered response of an animal to its environment is well established, detectable changes in behavioral patterns do not necessarily establish whether the change is positive or negative for the animal's continued success. The observed behavioral changes do, however, suggest specific areas in which future research should be focused. The behavior mechanisms employed in this study are purported to be reliable. How well they fit into an experimental schedule over a range of wild avian species representative of those found in most parts of the country remains to be demonstrated.

1.2 Personnel and Program Organization

This program was conducted by a cohesive and experienced team consisting of an ethologist, behavioral and physiological ecologists, physiologists, pathologists, physicists and biophysicists with specialties in ornithology and microwave generation and measurement.

Dr. S. P. Battista of Arthur D. Little served as Principal Investigator with Drs. E. J. Cook of Arthur D. Little, T. H. Kunz and F. E. Wasserman of Boston University, and K. A. Youngstrom of Manomet Bird Observatory serving as Co-Investigators. The project coordinator was Dr. D. Byman.

As shown in the Organizational Chart (Figure 1-1), Dr. Cook was reponsible for microwave generating equipment, calibration and monitoring of exposure


DOE/EPA
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J. W. Allis, Ph.D.
PROGRAM MANAGER
D. Byman, Ph.D.
ARTHUR D. LITTLE, INC.
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H. S. Ho, Ph.D.
K. P. Able, Ph.D.
V. Tucker, Ph.D.

*Co-investigators

FIGURE 1-1: ORGANIZATIONAL CHART OF KEY PERSONNEL

levels; Dr. Kunz and Mr. Youngstrom for birds. In addition, the program included Mr. Michael Grossman, a statistician from Arthur D. Little, and Dr. F. Wasserman, an avian ethologist from Boston University. A Review Committee consisting of Dr. C. J. Kensler, Senior Vice President of Arthur D. Little, and Dr. I. Miller, Vice President of Arthur D. Little, Dr. I. P. Callard, Chairman of the Department of Biology of Boston University; and Ms. K. S. Anderson, Executive Director of Manomet Bird Observatory, convened at intervals to follow the progress of the program and serve in an advisory capacity to review, critique and assist in the overall program.

In view of the extensive diversity of the proposed program, it was necessary to supplement the professional staff with a number of consultants. Two of our consultants, Drs. C. Maletskos and S. F. Cleary, have wide experience as biophysicists with specialities in defining hazards related to exposure to various forms of electromagnetic radiation, including microwave. Other consultants were Dr. S. W. Nielson, a veterinary pathologist with experience in avian diseases; Dr. H. S. Ho, a specialist in microwave dosimetry; Dr. K. P. Able, a specialist in bird migratory orientation; and Dr. V. Tucker, a specialist in avian flight (in wind tunnel).

1.3 Rationale

The proposed studies were designed to provide, where possible, dose-response data that reflect the effects of microwave radiation at 2.45 GHz on the behavior and physiology of birds. A number of different endpoints were used to determine the responses to microwave radiation ranging from 0.1 and 25 mW/cm^2 and in some cases in excess of 100 mW/cm^2.

In all experiments, especially at the higher power densities, no attempt was made to ascertain whether observed responses were related to non-thermal effects. Deep body (core) temperatures were recorded in representative numbers of exposed animals. Body temperature cannot be measured using conventional methodology during irradiation due to perturbations in the microwave field as well as in the temperature sensor itself. For this reason it was necessary to use temperature probes that are not sensitive to microwaves or, alternatively, to make measurements before and after irradiation or during a brief period of interruption in irradiation using conventional devices.

In determining possible adverse effects of microwave radiation on various organ functions, several types of responses were considered. One type was the transient response, i.e., reponses that are manifested only during exposure. Another was the response that occured during irradiation and persists after termination of the irradiation. A third type is a response that is not observed during irradiation but requires a latent period before expression, e.g., teratology. Responses or changes in response that persist or appear long after termination of irradiation, are useful indicators of hazard.

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2.0 CONCLUSIONS

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- Aversion/attraction experiments (see Section 4.1) were conducted to determine whether birds can perceive the presence of microwave irradiation by observing whether House Finches (*Carpodacus mexicanus*) and Blue Jays (*Cyanocitta cristata*) exhibit an attraction or an aversion to the field when exposed to power densities of 10, 25 and 50 mW/cm^2.

At all three power densities to which groups of House Finches were exposed, each group showed non-random movement within the test cage based on the number of times that birds were observed in the irradiated and non-irradiated areas.

At 10 mW/cm^2 and a mean ambient temperature of 23.4°C, House Finches exhibited behavior consistent with attraction to the field since the birds were observed to perch more often in the exposed areas of the cage during microwave irradiation than in the shielded areas. At a power density of 25 (and a mean ambient temperature of 22.4°C) or 50 mW/cm^2 (and a mean ambient temperature of 21.1°C), House Finches were observed to perch more frequently in the non-irradiated areas of the cage, suggesting an aversion to the microwave field.

At power densities of 10, 25 and 50 mW/cm^2 (temperature = 19.1°C to 19.6°C), Blue Jays also showed non-random movement within the test cage. The number of times that birds were observed in the exposed and shielded areas of the cage was not independent of experimental period (pre-exposure, exposure, and post-exposure periods). Thus, the results indicate that Blue Jays exhibit an aversion of microwave irradiation at these three power densities.

Based on these results, birds exposed to microwave irradiation at a rectenna site would appear to be capable of responding to the field by either avoidance or attraction depending upon the power density of the field.

- Orientation experiments (see Section 4-2) were carried out to determine whether microwave irradiation at 0, 6.8 and 23 mW/cm^2 for 90 minutes disrupts the ability of birds to migrate properly. Microwave exposure did not change the quantity of nocturnal activity, or "zugunruhe," exhibited by birds (White-throated Sparrows). Microwaves also did not affect the ability of birds to maintain oriented movements. Approximately one third of all birds tested maintained directional behavior, regardless of the amount of cloudiness or other environmental variables. There was, however, one discernible effect of microwave irradiation. The non-treated birds showed non-randomly distributed movements on nights with clear skies ($p = .07$) and on all nights ($p = .02$), i.e., combined clear and cloudy. The distribution movements of microwave treated birds were found to be random ($p > .05$). The greater dispersion in direction appears to be due to effects of microwave.

- The effects of acute microwave radiation on the behavior and position of birds within a flock dominance hierarchy were studied in White-throated Sparrows (Zonotrichia albicollis) and Dark-eyed Juncos

(Junco hyemalis) (see Section 4.3). Both species congregate naturally in small flocks in winter and were kept in captive flocks of six birds each. Seventeen birds among twelve flocks were exposed to four combinations of different microwave density and duration along with three sham control birds from two additional flocks. Although the irradiated birds maintained their positions in the hierarchies (with one exception), some appeared to change their level of aggression after exposure of 25 mW/cm^2. These changes, however, are not considered inconsistent with survival of birds in the SPS rectenna site.

- Lethal levels of microwave irradiation were determined in Dark-eyed Juncos (see Section 4.3). Birds were exposed to microwave power densities in excess of those proposed for the SPS system, i.e., 130 mW/cm^2, 150 mW/cm^2, or 160 mW/cm^2. The lethal level of microwave irradiation for the Dark-eyed Junco exposed at an ambient temperature of 7 to 13°C appears to be on the order of 150-160 mW/cm^2 over 7.25 ± 0.5 minutes. Power densities of 100 to 130 mW/cm^2 for up to 20 minutes results in no observable signs of heat stress other than gaping over a twenty minute exposure. Exposure to near lethal levels of microwave irradiation results in stress-related behaviors that are characterized by gaping, panting, crouching and loss of muscular coordination or of equilibrium. The rapid onset of gaping has been observed at all power levels from 25 mW/cm^2 to 160 mW/cm^2 as soon as 30 seconds after the start of exposure.

- To investigate the relationship between microwave exposure and the onset and duration of patterns of thermoregulatory behaviors, a series of experiments were carried out with House Finches (small sized bird -- 17 to 24 g) and Blue Jays (medium sized bird -- 75 to 100 g) at each of five power densities: 0.1, 1, 10, 25, and 50 mW/cm^2 (see Section 4.4).

House Finches and Blue Jays show behavioral responses to microwave induced heat stress which are good indicators of increased cloacal temperatures during microwave irradiation. For both species, studies of behavior and cloacal temperature indicate that there is no observable thermoregulatory stress induced by microwave irradiation of 10 mW/cm^2 or less. At 25 mW/cm^2, House Finches are only slightly stressed by the irradiation while Blue Jays exhibit greater degree of thermoregulatory behavior. Thus bird species whose body mass is equal to or greater than that of Blue Jays (85 g) may experience some degree of thermal stress when exposed to a 25 mW/cm^2 microwave field. Ambient temperatures during the House Finch experiments ranged from 22.2°C to 28.3°C ($\bar{x}$ = 24°C, S.D. = 1.9) and relative humidity from 67% to 79% ($\bar{x}$ = 71%, S.D. = 14). During the studies of thermoregulatory behavior in Blue Jays ambient temperature ranged from 20.0°C to 21.7°C ($\bar{x}$ = 20.6°C, S.D. = 0.5) and relative humidity ranged from 36% to 66% ($\bar{x}$ = 43%, S.D. = 9).

At 50 mW/cm^2, both House Finches and Blue Jays exhibit signs of thermal stress and show significant elevation in cloacal temperature during 10 minutes of irradiation. Blue Jays showed an elevated behavioral response suggesting that they must expend more energy for heat dissipation than House Finches for similar rises in cloacal temperature.

The orientation of a bird's body with respect to the E vector of the microwave field is important in determining the magnitude of thermal stress. Both House Finches and Blue Jays experience significantly greater elevation in cloacal temperature when the longitudinal axis of the body was oriented parallel to the E vector than when the birds were oriented perpendicular to the E vector. At 50 mW/cm^2, parallel orientation proved lethal for some House Finches after nine minutes of irradiation.

- Molt, the cyclical replacement of feathers, is essential to mating and the adaptation of birds to a variety of environmental changes. All birds molted successfully after continuous exposure to microwaves for up to 18 weeks at power densities of 1, 10 and 25 mW/cm^2 (see Section 4.5).

- Foraging behavior was studied in White-throated Sparrows to determine the effect of acute and chronic continuous wave microwave radiation using a basic optimal foraging technique (see Section 4.6). Birds were exposed to microwaves at power densities corresponding to power levels that would be expected in an SPS based rectenna site. Three basic experiments were performed: (1) acute multiple (brief), (2) seven day, and (3) four week continuous exposures.

At power densities of 0.0, 0.1, 10.0, and 25.0 mW/cm^2 for 2, 20 or 200 minutes, foraging efficiency was influenced by changes in ambient temperature and relative humidity, but no acute effects were correlated with levels of microwave exposure.

Seven day continuous exposures resulted in no significant differences in foraging behavior between sham and microwave treated birds. Significant differences in foraging efficiency were found among birds receiving different power densities but the differences were not found to be dose-related.

Four week continuous exposures were conducted at power densities of 0.0 and 25.0 mW/cm^2. Birds exposed to microwave irradiation showed no significant differences in foraging efficiency between pre-exposure, exposure, and post-exposure periods despite significant differences in ambient room and exposure chamber temperatures. When compared to sham (parallel) control birds, microwave treated birds showed a significantly lower search efficiency during the post-exposure period.

- Reproductive behavior was studied in the Zebra Finch (see Section 4.7). In view of the likelihood of birds entering and nesting within the SPS rectenna site, it is essential to determine the effects of microwave irradiation on reproductive success.

Birds exposed to continuous microwave radiation (25 mW/cm^2) were able to breed successfully. There was no significant difference in the clutches produced, eggs per clutch, fertile eggs per clutch, hatchlings per clutch or number of fledglings produced by the irradiated and control pairs of birds. This may simply show that the Zebra Finch already has the ability to compensate for environmental factors which may affect its reproductive success; perhaps clutches of eggs always include "extras" to compensate for problems of infertility. Thus no notable effect of microwave exposure on reproductive behavior was observed at 25 mW/cm^2.

- The effect of 25 or 50 mW/cm^2 microwave irradiation on embryonic development in bird eggs exposed in the field when incubating parents are absent from the nest was studied by irradiating fertile Coturnix Quail eggs twice a day for 30 minutes throughout the 17 day normal incubation period (for this species) (see Section 4.7). The hatchability of eggs irradiated by 25 mW/cm^2 did not differ from that of eggs from any of the control groups, whereas the hatchability of eggs irradiated by 50 mW/cm^2 was significantly lower than that of control eggs. No significant differences were observed in the rates of growth of chicks hatched from control and 25 mW/cm^2 eggs during the first 26-28 days post-hatch nor from control and 50 mW/cm^2 eggs during the first 15 days post-hatch.

No evidence of teratogenesis was observed as indicated by the absence of deformed chicks hatched from eggs that had been microwave irradiated at 25 or 50 mW/cm^2.

Based on these data, microwave irradiation by 25 mW/cm [illegible] should not notably reduce egg hatchability in the field.

- The effect of microwave irradiation on bird flight was studied in a wind tunnel on Budgerigars flying in a wind 37 km/h (see Section 4.8). When irradiated by 50 mW/cm^2 microwaves, birds began to show high levels of stress at ambient temperatures above $26^{\circ}C$ and demonstrated an inability to fly for 10 minutes at air temperatures above $32^{\circ}C$. At air temperatures above $33^{\circ}C$, budgerigars required at least 10 minutes to recover fully after flights involving exposures of 50 mW/cm^2. Budgerigars irradiated during flight generally showed higher body temperatures than did birds flown without microwaves when air temperatures were above $28^{\circ}C$. Based on these data, at air temperatures above $28^{\circ}C$, a microwave field of 50 mW/cm^2 could impair bird flight in the field, forcing the bird to engage in thermoregulatory behaviors and land prematurely. The long post-flight cooling period might adversely affect a bird's ability to forage or escape predators.

- A thermal model was constructed from dosimetry data obtained in the laboratory and from data in the literature (see Section 5.0). The model provides estimates of the maximum tolerated level of microwaves over a range of different ambient conditions of wind speed, humidity and air temperature.

3. METHODS

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The methodology described here is related to the equipment used to generate, deliver and measure microwave irradiation. A description of the methodology used to study the various behaviors of birds is provided within each of the corresponding sections.

3.1 Exposure Facilities and Microwave Generating Equipment

3.1.1 Exposure Facilities

In addition to the indoor irradiation facility at Arthur D. Little, an outdoor cage complex and microwave exposure facility was constructed at Manomet Bird Observatory for a series of acute social-interaction studies. With necessary modifications this facility was also used for the migratory orientation studies.

3.1.2 Microwave Illuminator Design

The microwave irradiation facilities were designed to provide planewave illumination with a power density variation of ± 0.5 dB maximum over the cages, and/or flight area, during all acute and short-term chronic studies. The radiating source for all experiments was a standard-gain horn which provides linearly polarized radiation.

The standard-gain horn selected for this program was the Narda #645. It is a precision cast, one-piece unit which shows great uniformity in performance over a production lot. The on-axis gain of this horn at 2,450 MHz was 14.57 dB relative to an isotropic radiator, and use of the universal response curves for sectoral horns[1] indicated that the Narda #645 would provide power uniformity within ± 0.5 dB over a region that lies within 7 degrees of the axis. This is shown in Figure 3-1 along with a tabulation of the normalized power density and maximum cage dimensions for ± 0.5 dB power density uniformity at various distances from the radiating source.

3.2 Exposure Chambers and Cages

The acute-exposure studies at Manomet required only the illumination of a 15 x 15 x 15 cm microwave transparent cage. Thus, any horn-to-cage spacing of 1.37 meters provided the required field uniformity. A simple overhead mounting of the horn sufficed, as shown in photograph, Figure 3-2. The supporting tower was provided with a number of cross rails on which the exposure platform could be placed at different distances from the horn. By varying the horn-to-platform spacing, and by adjusting the microwave power generator control (which varies the output over the range of 85 watts to 1,080 watts), the power density at the surface of the platform could be varied from about 1 mW/cm^2 to over 100 mW/cm^2. The platform and the tower rails were covered with anechoic material and the cage holding the bird to be exposed was centered under the horn. The microwave power source was located in a metal shed adjacent to the tower. From this same shed, observations were made of bird behavior before, during and after exposure. A

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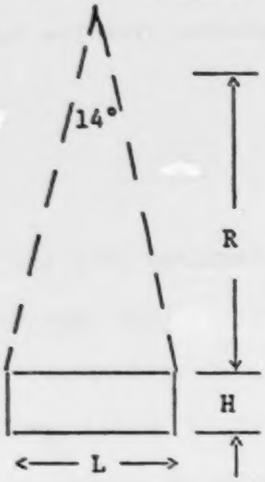
(1) Henry Jasik (Editor), "Antenna Engineering Handbook," Chapter 10, Figures 10-3 and 10-4, McGraw Hill Book Company, 1961.

Chamber Design Parameters



$$P_D\Big]_{Axis} = 28.62\ P/4\Pi\ R^2$$

where P = total radiated power.

For $\Delta\ P_D \leq 0.5$ dB,

$L \leq 2R \tan 7°$

$H \leq 0.11\ R$

R(Meters)	1	2	4	6	8	10
R(Feet)	3.28	6.56	13.1	19.7	26.2	32.8
max L(Feet)	0.81	1.61	3.22	4.84	6.93	8.05
max H(Feet)	0.36	0.72	1.44	2.17	3.10	3.61
$P_D/P\ (10^{-6}\text{cm}^{-2})$	228	56.9	14.2	6.33	3.56	2.28

FIGURE 3-1

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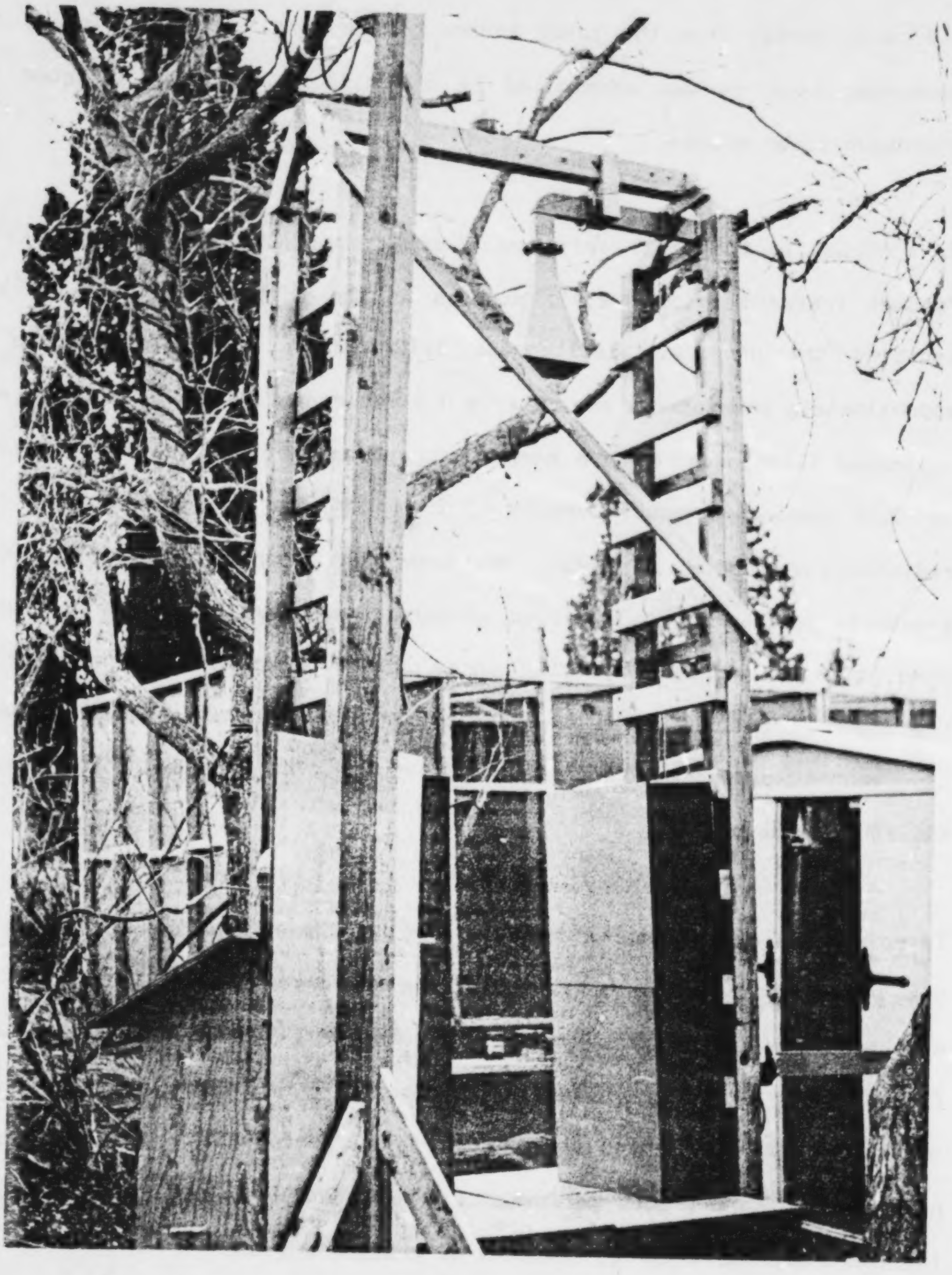

FIGURE 3-2

waveguide transmission line of about 5.5 meters was used to carry the microwave energy from the power source to the horn. The duration of the microwave exposure was controlled by a digital timer that actuated the microwave power source.

In contrast to the small orientation cages used for irradiating birds at Manomet (refer Section 4.2.4), studies at the Arthur D. Little facility required the uniform, simultaneous illumination of multiple cages of approximately one meter x one meter x 0.6 meter each. Four such cages were uniformly illuminated with a horn-to-cage spacing of at least 7.3 meters. At this spacing, a power densitv of 25 mW/cm_2 was achieved with a total radiated power of about 4.6KW. The Cober S6F generators, which are 6 KW microwave power sources, provided adequate power margin. These generators were industrial units employing three phase, saturable core regulation. Measurements indicated the presence of 180 Hz amplitude modulation which may reach 60 percent at low generator output, <1KW, but declines to about 40% above 3 KW output.

To reduce the overhead space required for the chronic exposure chamber, and yet provide the minimum 7.3 meter horn-to-cage spacing, a folded-path chamber design was originally designed. Figure 3-3 shows the original configuration. However, initial testing of the folded-path approach showed excessive loss of floor space due to field perturbation by the anechoic horn shield and degraded performance of the anechoic wall covering due to increased microwave energy incident at grazing angles.

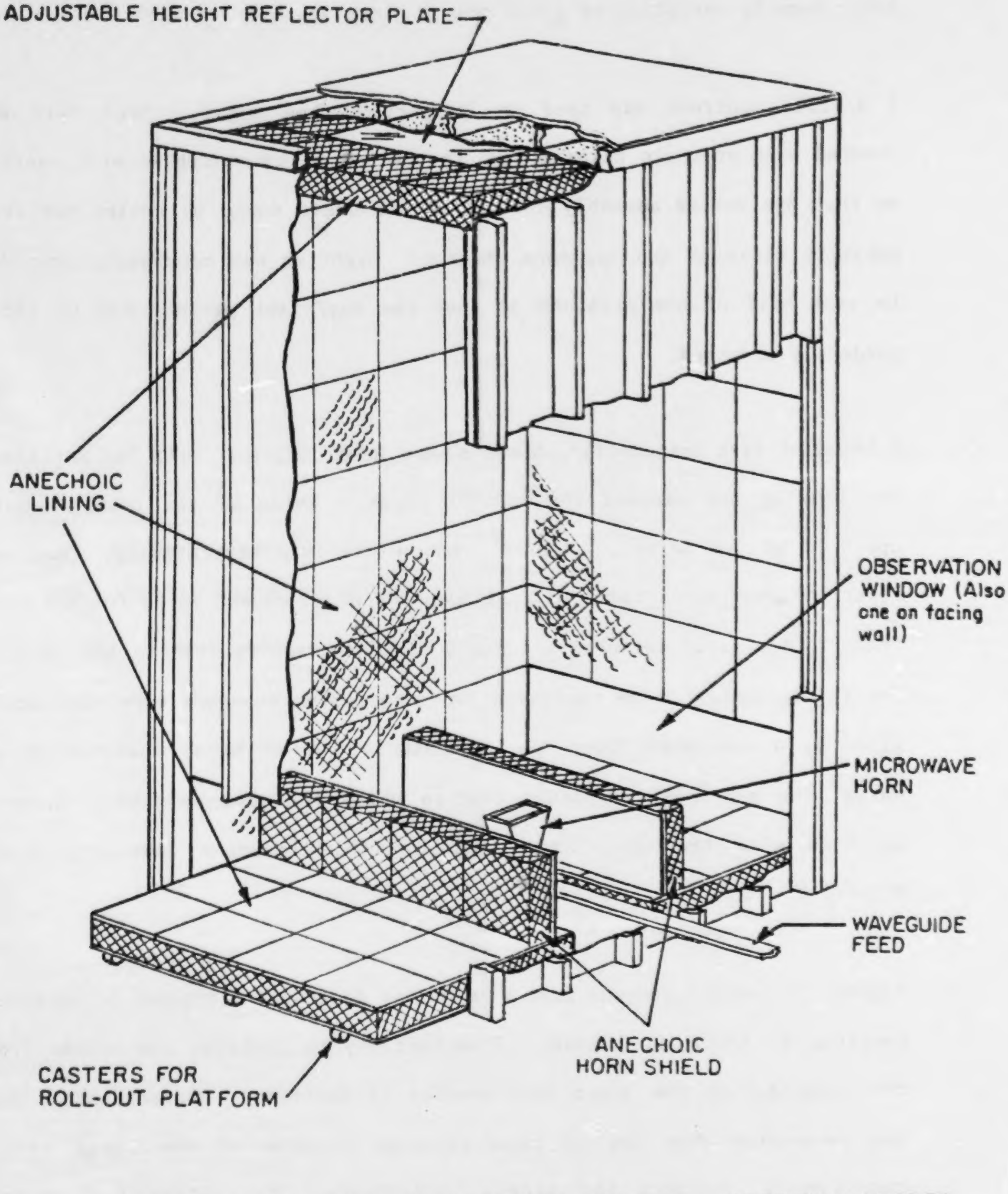
ADJUSTABLE HEIGHT REFLECTOR PLATE
ANECHOIC LINING
OBSERVATION WINDOW (Also one on facing wall)
MICROWAVE HORN
WAVEGUIDE FEED
ANECHOIC HORN SHIELD
CASTERS FOR ROLL-OUT PLATFORM

FIGURE 3-3 MICROWAVE IRRADIATION CHAMBER - ORIGINAL DESIGN

As a consequence of these test results, the horns were repositioned for overhead illumination. This configuration shown in Figure 3-4 yielded a power density variation of ± 1dB over a floor space of 4' x 6'.

A divided platform was used for support of the cages. Each half was covered with anechoic material and the bottom platform fitted with casters so that the entire assembly containing the cages could be rolled out from opposite sides of the exposure chamber. Lighting was separately provided to each half of the platform so that the day/night periods may be independently adjusted.

A total of five irradiation chambers were used, together with two replicas, for housing and heating the control birds. Three of the chambers were operated at 0.1 mW/cm^2, 1 mW/cm^2, and 10 mW/cm^2, respectively, from one Cober S6F generator, using topwall couplers of 20 dB and 10 dB for the horn feeds to the first two chambers and a direct waveguide feed to the horn in the third chamber. The remaining two irradiation chambers were each energized by a dedicated Cober SF_6 generator. One of these operated at 25 mW/cm^2 for subchronic exposure studies while the other was used in conjunction with the wind tunnel and for those studies involving acute exposures.

Figure 3-5 shows a general plan view of the dedicated microwave irradiation facility at Arthur D. Little. This facility is isolated and remote from the remainder of the Acorn Park complex in Cambridge, Massachusetts, and was renovated for use in this program because of the large space requirement, concern for safety (microwave high voltages), and for security.

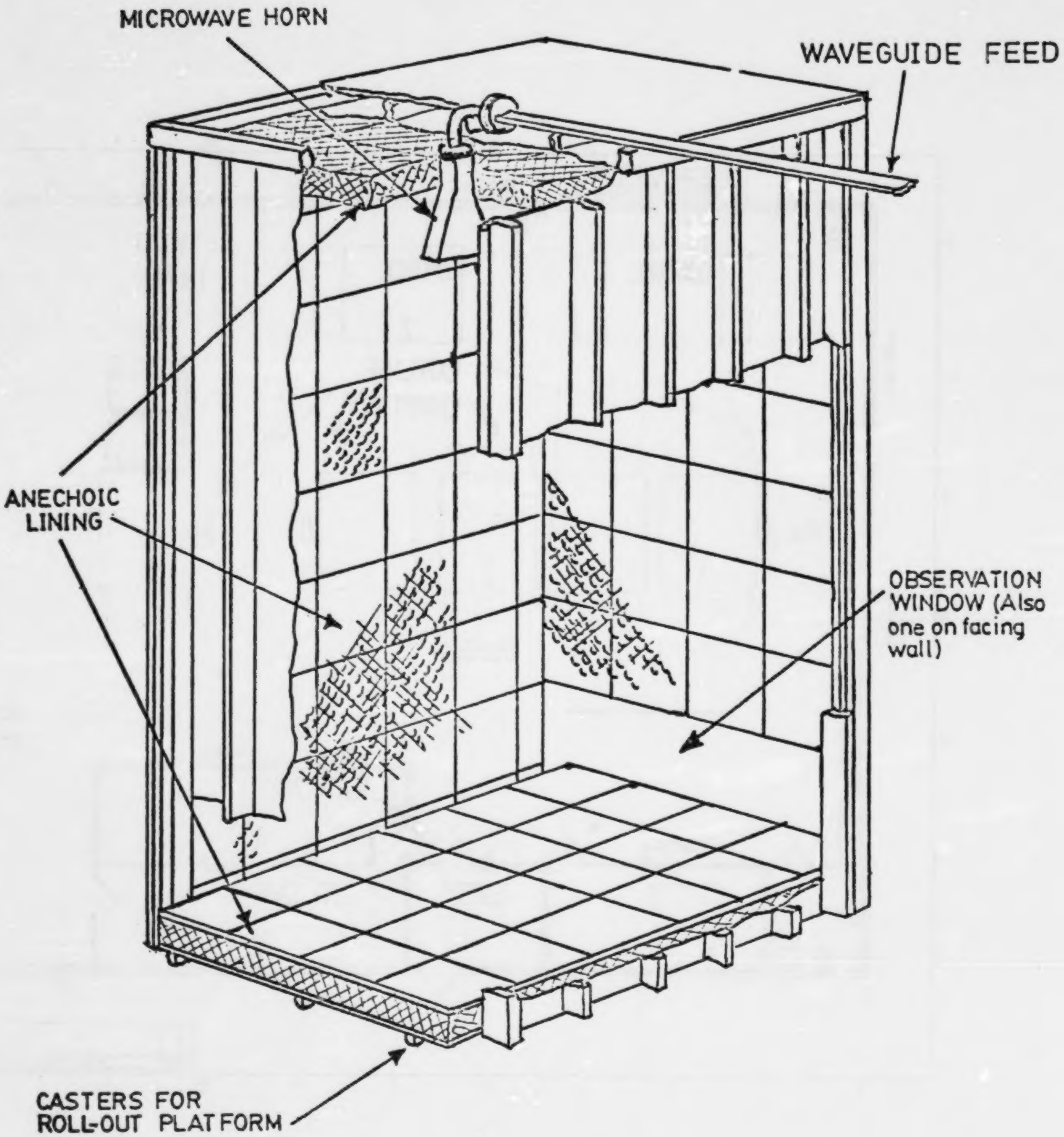
MICROWAVE HORN
WAVEGUIDE FEED
ANECHOIC LINING
OBSERVATION WINDOW (Also one on facing wall)
CASTERS FOR ROLL-OUT PLATFORM

FIGURE 3-4 MICROWAVE IRRADIATION CHAMBER - FINAL DESIGN

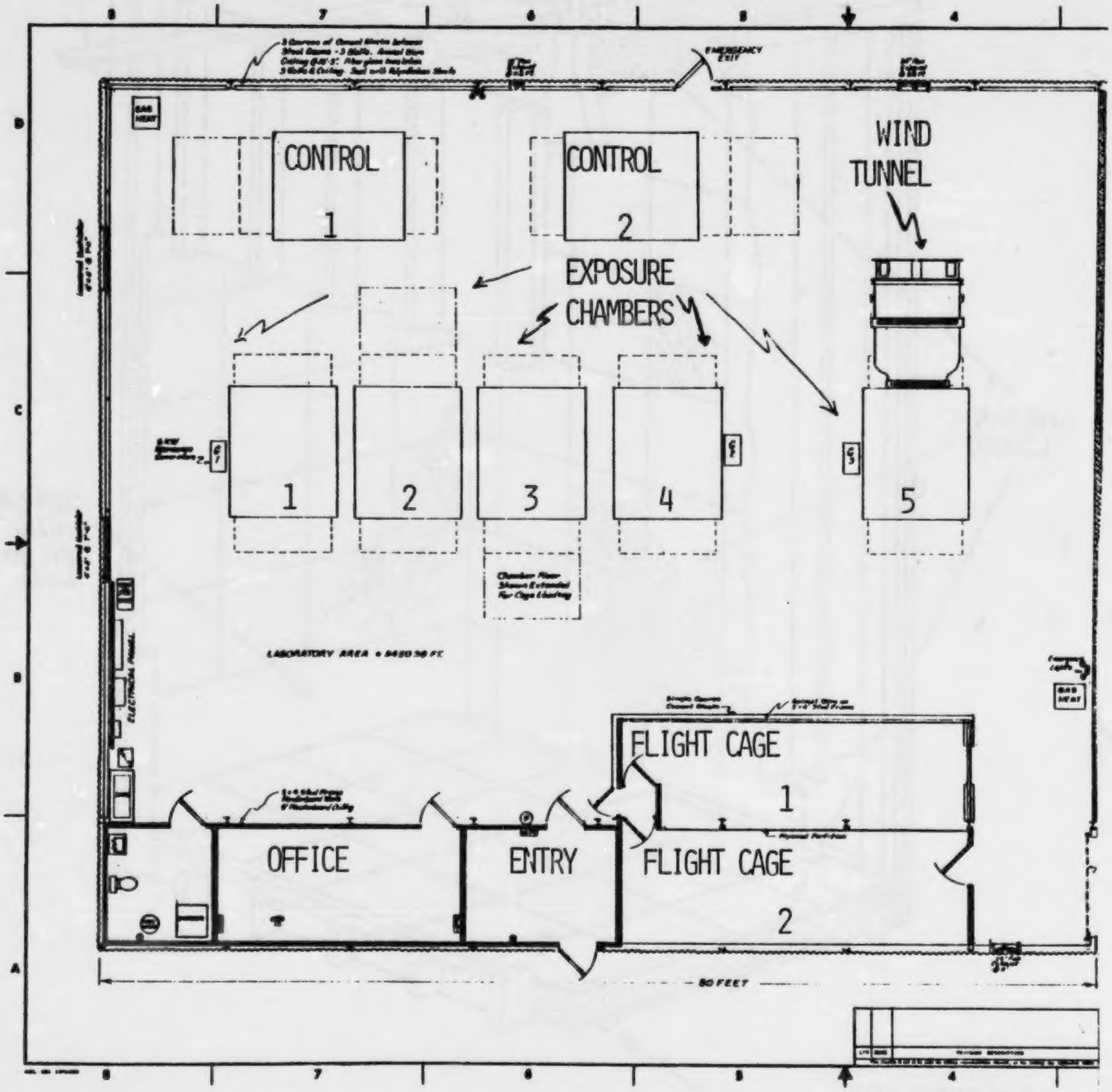
8
7
6
5
4
D
C
B
A
EMERGENCY EXIT
CONTROL 1
CONTROL 2
WIND TUNNEL
EXPOSURE CHAMBERS
1
2
3
4
5
LABORATORY AREA
FLIGHT CAGE 1
FLIGHT CAGE 2
OFFICE
ENTRY
80 FEET

Figure 3-5

Floor Plan of Microwave Irradiation Facility

3.3 Wind Tunnel Design

In collaboration with Dr. Vance Tucker of Duke University, a wind tunnel was designed and built for the training of birds to fly. A major wind tunnel design requirement was that the air flow direction in the flight chamber be adjustable 1 degree down to 7 degrees up relative to a horizontal plane. The upwards air flow was needed to facilitate the initial training of the birds and for establishing a soaring mode of flight, while the downwards flow was needed to increase the flight effort and bring the birds to a highly stressed metabolic state. This requirement, together with considerations of cost, an increased appreciation of the relatively modest requirements on air flow uniformity and turbulence for bird flight, and the apparent insensitivity of the birds to fan noise, led to the selection of an open-jet wind tunnel design. Figure 3-6 shows the wind tunnel and flight chamber configuration which consists of two fans, placed side by side, followed by a honeycomb flow straightener, a contraction nozzle, a second flow straightener, the working chamber, and finally an outlet diffuser. The tilt-frame was designed so that the load of the fans and ducting is carried on the hydraulic rams, the floor level pivot, and the rear pivot. An essentially unloaded, position-stabilizing pivot is established through the center of the wind tunnel, and it is about the axis that the airstream was tilted. An additional advantage of the upstream fans was that the air velocity in the flight chamber could be controlled by restricting the air flow to the fans through the use of blocking latticeworks of different open area placed in front of the air inlet. This tech-

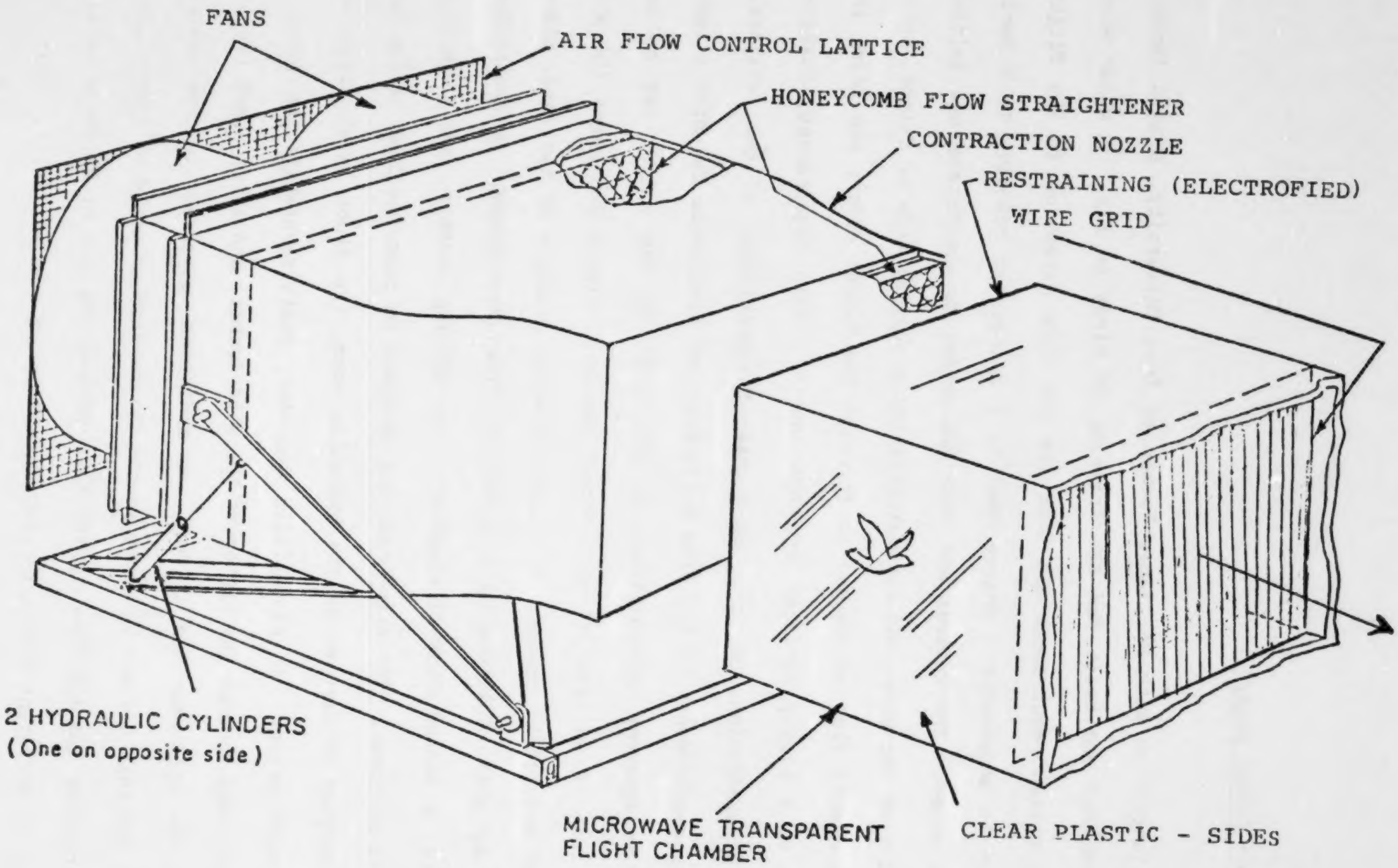
FANS
AIR FLOW CONTROL LATTICE
HONEYCOMB FLOW STRAIGHTENER
CONTRACTION NOZZLE
RESTRAINING (ELECTROFIED) WIRE GRID
2 HYDRAULIC CYLINDERS (One on opposite side)
MICROWAVE TRANSPARENT FLIGHT CHAMBER
CLEAR PLASTIC - SIDES

FIGURE 3-6 WIND TUNNEL AND FLIGHT CHAMBER

nique allowed the use of constant speed fan motors rather than the far more expensive variable speed motors used in tunnels with downstream fans.

The specifications for the tunnel are as follows:

Fans	2-each 42" diameter, 10 horsepower
Flight Chamber	1 x 1.4 meter-normal to air flow
Air Velocity	Adjustable in steps, (16-64 km/h (10-40 mph)
Air Flow Uniformity	Maximum 5% velocity variation 0.5 degree directional variation
Turbulence	Maximum 5%
Tilt	Continuously variable, 1 degree down to 7 degrees up

Figure 3-7 shows a view of the air inlet end of the wind tunnel. The wind tunnel/microwave irradiation chamber interface occurred at the end of the wind tunnel nozzle section. The flight cage was placed inside the exposure chamber where it rested on a wooden platform raised above the anechoic floor of the chamber.

As designed, independent control of the air stream temperature and humidity was not used in order to provide conditions that approximated the outdoor ambient at the time of the experiment. Thus, by scheduling enough experiments throughout the year, the desired range of test conditions could be achieved. Dedicated instrumentation provided measurement of air velocity, temperature, and relative humidity.

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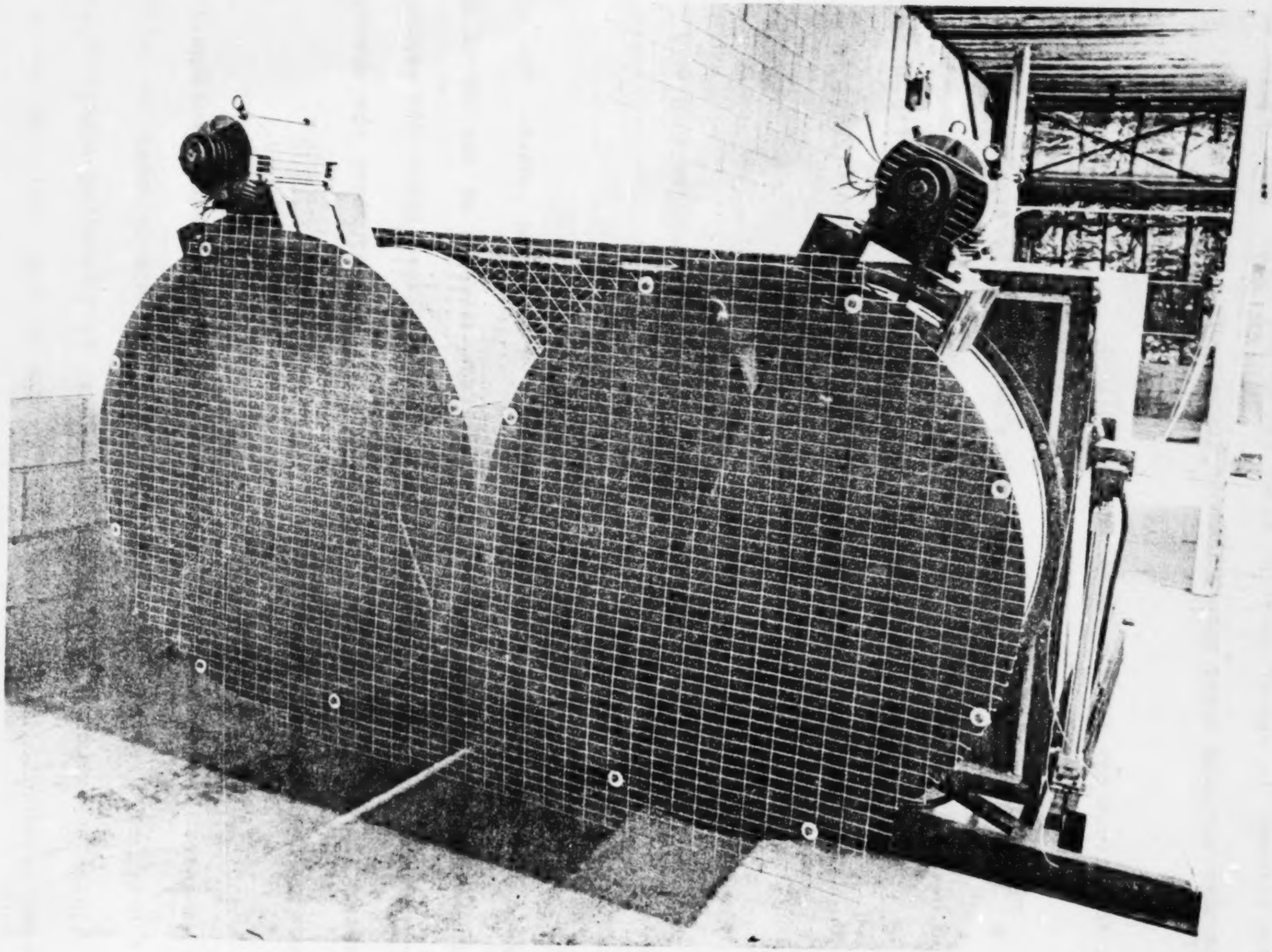

Figure 3-7 Wind Tunnel

For flight training and exposure of budgerigars, a 1 x .6 x .6 m cage with four solid transparent sides and two screeened ends was placed in the airstream of the wind tunnel approximately 0.54 m from the outlet honeycomb flow straightener. The flow was adjusted to provide a velocity of 37 km/h at the level of the training perch, and a variation of < 2.4 km/h was measured over the remainder of the cage.

4.0 EXPERIMENTAL

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4.1 AVERSION/ATTRACTION

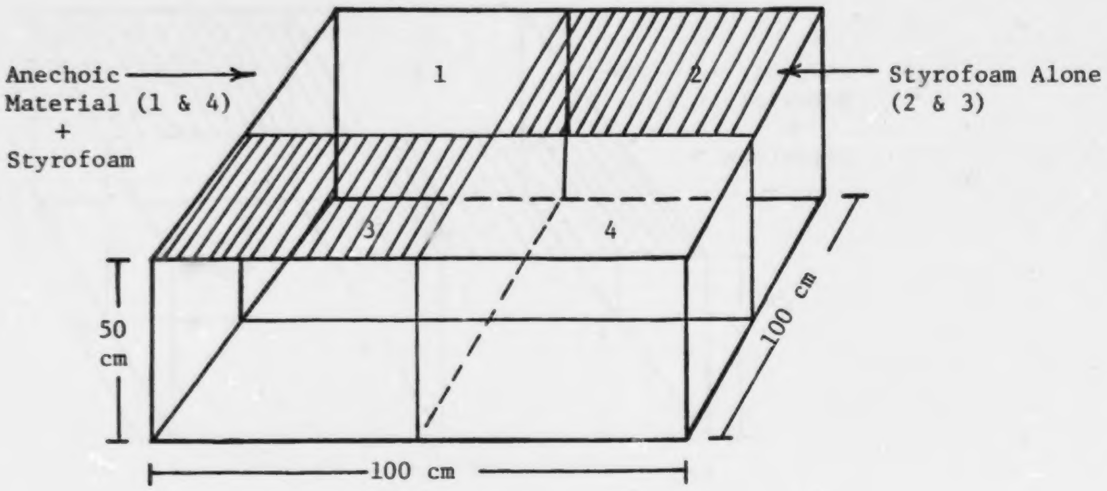
4.1.1 Introduction

The goal of these experiments was to determine whether birds can perceive the presence of microwave irradiation by observing whether House Finches (Carpodacus mexicanus) and Blue Jays (Cyanocitta cristata) exhibit attraction or an aversion to the field when exposed to power densities of 10, 25, and 50 mW/cm^2. In an attempt to address this issue, experiments were conducted to test the hypothesis that a bird's movement within a symmetrical cage would be random; thus, the time spent in areas irradiated with microwaves would not differ from time spent in areas devoid (shielded) of microwaves.

4.1.2 General Procedure

The aversion/attraction behavior of House Finches and Blue Jays was studied in a 100 cm x 100 cm x 50 cm test cage, divided into quadrants which were labeled 1 through 4 as shown in Figure 4-1. The cage was mapped for field uniformity. Diagonally opposed quadrants were shielded from microwave irradiation by placing anechoic material over these areas. This procedure resulted in areas of zero mW/cm^2 adjacent to areas irradiated with 10, 25, or 50 mW/cm^2. The top of the cage was first covered with a sheet of white styrofoam so that the entire top surface of the cage would appear homogenous as it would hide the anechoic material from the birds. The anechoic material was positioned so that either quadrants 1 and 4 or quadrants 2 and 3 were designated as exposure areas. Placement of anechoic material in this manner created an area in the middle of the cage where the change in

Figure 4-1: A) AVERSION/ATTRACTION CAGE SHOWING THE QUADRANTS AND PLACEMENT OF ANECHOIC MATERIAL


Anechoic Material (1 & 4) + Styrofoam
1
2
Styrofoam Alone (2 & 3)
3
4
50 cm
100 cm
100 cm

B) AVERSION CAGE SHOWING PATTERN OF IRRADIATION AND PLACEMENT OF PERCHES - TOP VIEW

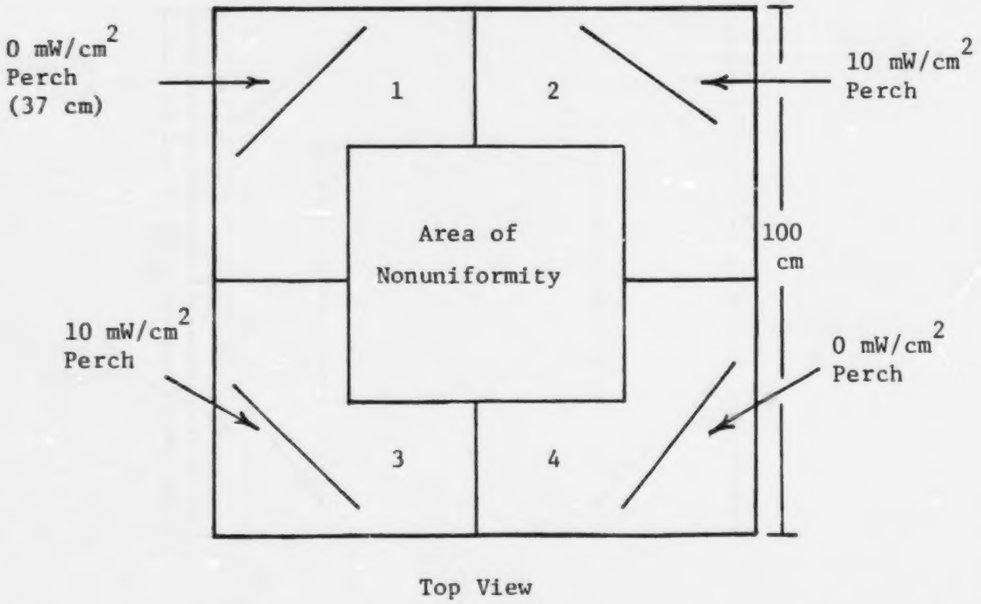
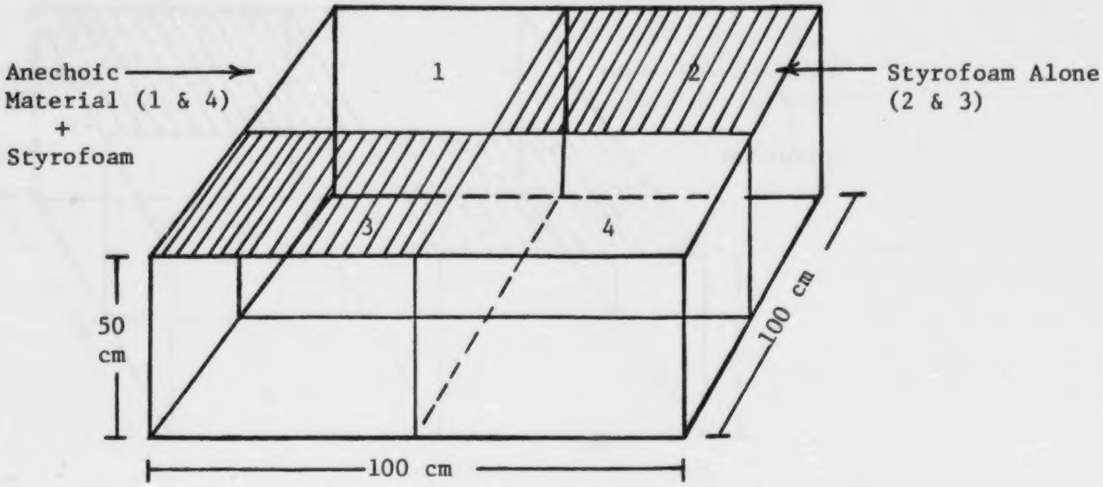
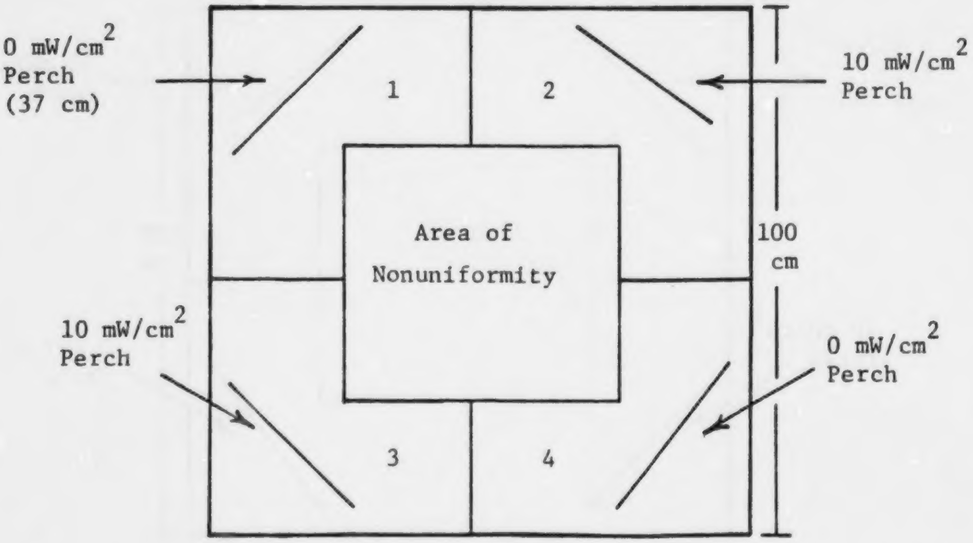

0 mW/cm^2 Perch (37 cm)
1
2
10 mW/cm^2 Perch
Area of Nonuniformity
100 cm
10 mW/cm^2 Perch
0 mW/cm^2 Perch
3
4
Top View

Figure 4-1: A) AVERSION/ATTRACTION CAGE SHOWING THE QUADRANTS AND PLACEMENT OF ANECHOIC MATERIAL


Anechoic Material (1 & 4) + Styrofoam
Styrofoam Alone (2 & 3)
1
2
3
4
50 cm
100 cm
100 cm

B) AVERSION CAGE SHOWING PATTERN OF IRRADIATION AND PLACEMENT OF PERCHES - TOP VIEW


0 mW/cm²
Perch
(37 cm)
10 mW/cm²
Perch
1
2
Area of Nonuniformity
100 cm
10 mW/cm²
Perch
0 mW/cm²
Perch
3
4

Top View

areas, independent of experimental condition. A significant difference would be used as a means of ascertaining whether the birds were indifferent or responded by aversion or attraction to microwave irradiation.

Birds did not spend all of their time on the perches provided in the cage, but often perched on the sides or hopped on the floor of the cage. In order to eliminate the uncertainty of whether the bird on the floor of the cage was being exposed to the specified level of microwaves, data where birds were observed on the floor of the cage were excluded from the analysis. Because the sides of the cage have the same relative power density as that of the quadrant perches, data based on observations where the bird was clinging to the side of the cage were included with those where the bird was on the perch. Therefore, the total number of observations of birds in exposed or shielded areas is based only on observations in which the bird was observed on either the perch or on the side of the cage.

All birds were weighed before each three-hour experiment in order to monitor their general health. In addition, ambient temperature and relative humidity were recorded during each test along with chamber temperature for the exposed and shielded areas of the test cage. Temperature was recorded during the experiments with Blue Jays only, using a Hewlett Packard Digital Chart Recorder and a Narda Microwave Transparent Temperature Monitor. (This equipment was not available during experiments with House Finches.)

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TABLE 4-1

AVERSION/ATTRACTION OF BIRDS TO MICROWAVE FIELDS - HOUSE FINCHES

		*Number of times House Finches were observed in Area A or B		
POWER DENSITY	CAGE AREA	Pre-exposure	Exposure	Post-exposure
a) 10 mW/cm^2	A Shielded	1104	906	861
	B Exposed	792	992	912
	$\bar{X}$ ambient temperature = 23.4°C; $\bar{X}$ relative humidity = 72%			
	$X^2 = 51.3$, df = 2, $p < 0.01$			
b) 25 mW/cm^2	A Shielded	876	1133	959
	B Exposed	889	691	735
	$\bar{X}$ ambient temperature = 22.4°C; $\bar{X}$ relative humidity = 68%			
	$X^2 = 56.98$, df = 2, $p < 0.05$			
c) 50 mW/cm^2	A Shielded	860	993	925
	B Exposed	1012	721	806
	$\bar{X}$ ambient temperature = 21.1°C; $\bar{X}$ relative humidity = 47%			
	$X^2 = 53.05$, df = 2, $p < 0.01$			

---

*The total number of observations of House Finches in a symmetrical cage with two quadrants shielded from, and two quadrants exposed to, microwave irradiation at 10, 25, and 50 mW/cm^2. The null hypothesis being tested with a X^2 analysis (3x2 X^2 contingency tables, df = 2) is that the frequency of observations in the shielded and exposed areas of the cage is independent of the pre-exposure, exposure, and post-exposure periods. Observations were made every six seconds during the last ten minutes of each 30-minute period (pre-exposure, exposure, and post-exposure periods). Birds were observed continuously through a pre-exposure, exposure and post-exposure period. Each of 10 birds was tested twice.

greater number of birds perched in the unshielded areas during the pre-exposure period. There was a significant difference among the three mean ambient laboratory temperatures for the different microwave dosages (10, 25, and 50 mW/cm^2, $F = 8.01$, $df = 2, 57$, $p < 0.001$), however, the mean ambient laboratory temperature for the 25 mW/cm^2 exposures (22.4°C) was not significantly different from that measured for the 10 mW/cm^2 exposures (23.4°C; Student-Newman-Keuls, $p > .05$). Therefore the observed avoidance of the House Finch to microwave irradiation at the higher power cannot be explained alone by an elevated ambient temperature.

When exposed to 50 mW/cm^2, House Finches again spent less time in the exposed areas of the cage than in the shielded areas (3 x 2 X^2 contingency table, $X^2 = 53.05$, $df = 2$, $p < 0.01$). Before microwave irradiation the birds preferred the unshielded areas of the cage and after microwave irradiation there was an apparent lingering effect of microwave exposure, with the birds still showing a preference for the shielded areas during the post-exposure period. In five of the twenty trials (25%) conducted, House Finches that perched in the exposed areas of the cage for longer than 45 seconds showed thermoregulatory behaviors such as gaping and wing spreading. When these birds subsequently moved out of the exposed areas, the observed thermoregulatory responses ceased, thus providing additional evidence for the bird's ability to sense and display aversive movements to high levels of microwave irradiation; e.g., 50 mW/cm^2 field. The ambient temperature during the 50 mW/cm^2 exposures (21.1°C) was significantly cooler than for either the 10 or 25 mW/cm^2 exposures (Student-Newman-Keuls $p < 0.05$).

It is reasonable to postulate that the field intensities of microwaves at 25 and 50 mW/cm^2 were high enough to cause the birds to sense the irradiation and the resulting increase in thermal load and thus avoid exposed areas of the cage during the period of irradiation. The thermoregulatory behavior shown by some House Finches was comparable to the behavior observed previously in the thermoregulatory experiments (also on House Finches exposed to 50 mW/cm^2).

The aversion/attraction behavior of Blue Jays to 10, 25, and 50 mW/cm^2 is summarized in Table 4-2. Individual data for each bird studied are presented in Appendix 4.1-1. At all three power densities, Blue Jays showed non-random movement within the test cage. The frequency of observations in the exposed and shielded quadrants of the cage was not independent of the experimental period (pre-exposure, exposure and post-exposure periods) (Table 4-2). The results indicate that Blue Jays exhibit an aversion to microwave irradiation at these power densities. During microwave irradiation, at each of the three power densities (10, 25 and 50 mW/cm^2), birds showed a tendency to perch in the shielded areas of the cage. This was after there was a tendency to perch in the unshielded areas of the cage during the pre-exposure period. The ambient temperatures for these exposures were not significantly different, being 19.1°, 19.5° and 19.6°C for the 10, 25, and 50 mW/cm^2 experiments respectively.

Based on the chamber temperatures taken during the aversion/attraction studies of Blue Jays (Table 4-3), it is unlikely that differences in temperature between the shielded and exposed areas of the cage can account for the observed preference of Blue Jays to stay in shielded area. During the

TABLE 4-2

AVERSION/ATTRACTION OF BIRDS TO MICROWAVE FIELDS - BLUE JAYS

		*Number of times Blue Jays were observed in Area A or B		
POWER DENSITY	CAGE AREA	Pre-exposure	Exposure	Post-exposure
a) 10 mW/cm^2	A Shielded	875	961	996
	B Exposed	926	805	678
	$\bar{X}$ ambient temperature = 19.1°C; $\bar{X}$ relative humidity = 44%			
	$X^2 = 41.76$, df = 2, $p < 0.01$			
b) 25 mW/cm^2	A Shielded	716	1070	708
	B Exposed	887	661	766
	$\bar{X}$ ambient temperature = 19.5°C; $\bar{X}$ relative humidity = 50%			
	$X^2 = 110.58$, df = 2, $p < .001$			
c) 50 mW/cm^2	A Shielded	791	1113	1009
	B Exposed	947	663	762
	$\bar{X}$ ambient temperature = 19.6°C; $\bar{X}$ relative humidity = 53%			
	$X^2 = 108.22$, df = 2, $p < 0.01$			

*The total number of observations of Blue Jays in a symmetrical cage with two quadrants shielded from, and two quadrants exposed to, microwave irradiation at 10, 25, and 50 mW/cm^2. The null hypothesis being tested with a X^2 analysis (3x2 X^2 contingency tables, df = 2) is that the frequency of observations in the shielded and exposed areas of the cage is independent of the pre-exposure, exposure, and post-exposure periods. Observations were made every six seconds during the last ten minutes of each 30-minute period (pre-exposure, exposure, and post-exposure periods). Birds were observed continuously through a pre-exposure, exposure and post-exposure period. Each of 10 birds was tested twice.

TABLE 4-3

MEAN AMBIENT AND MEAN CHAMBER TEMPERATURES FOR AVERSION/ATTRACTION STUDIES WITH HOUSE FINCHES AND BLUE JAYS (INCLUDING THE ΔT ON SHIELDED AND EXPOSED SIDES OF THE AVERSION/ATTRACTION CAGE DURING STUDIES OF BLUE JAYS)

	10 mW/cm^2	25 mW/cm^2	50 mW/cm^2
House Finches			
Mean ambient (T°)	23.4	22.4	19.9
SD	2.6	1.1	1.2
Blue Jays			
Mean ambient (T°)	19.1	19.5	19.6
SD	0.8	0.6	0.4
Mean Δ Temp. in Exposed Area	2.0	3.0	4.4
SD	1.2	1.2	2.4
Mean Max. Temp. in Exposed Area	19.1	20.5	21.2
SD	1.8	6.5	5.1
Mean Δ Temp. in Shielded Area	1.8	2.5	2.9
SD	1.7	1.1	1.4
Mean Max. Temp. in Shielded Area	19.2	21.7	20.7
SD	1.7	1.7	2.0

10 mW/cm^2 exposures, the average maximum temperature of the shielded areas was 19.2°C (SD = 1.7); that for the exposed areas was 19.1° (SD = 1.8). These were not significantly different. For the 25 mW/cm^2 exposures, the maximum temperatures were 21.7° (SD = 1.7) and 20.5° (SD = 6.6) for the shielded and exposed areas respectively. At 50 mW/cm^2, maximum temperature for the shielded area was 20.7° (SD = 2.0), and was 21.2° (SD = 5.1) for the exposed areas. These results indicate that the Blue Jays' aversion behavior toward exposed areas of the test cage was not due to differences in temperature between exposed and shielded areas, but rather resulted from the presence of the microwave fields.

4.2 ORIENTATION

4.2.1 Introduction

Birds possess remarkable migratory capabilities. Annually, several hundred species of North American birds migrate from wintering ranges to breeding grounds and then return. These flights vary widely between and within taxa and may involve distances of several hundred to several thousands of kilometers. Birds migrate singly or in flocks that may contain enormous numbers of individuals. Migratory flights occur by day or night and are concentrated along narrow pathways or dispersed across broad fronts. Various environmental stimuli are perceived by birds and utilized as cues for directionality during migration. These include stellar patterns, geomagnetic lines of force, polarized light, meteorological conditions, visual landmarks and auditory stimuli. How these are ultimately used to determine directionality is not adequately understood. In particular, studies have focused on experiments to provide a better understanding of the mechanisms used by nocturnally migrating birds. The purpose of the present study has been to assess the effects of microwave exposure on the ability of one passerine nocturnal migrant to orient successfully during the period of seasonal migration.

Prior to migration, birds undergo extensive physiological alterations in preparation for the flight. These changes are stimulated by internal hormonal rhythms which in turn respond to various environmental cues; the most important being photoperiod and meteorological conditions. Many birds deposit large quantities of visceral and subcutaneous fat that serves as an energy source for the migratory flight, replace various feathers, and enlargement in the mass of important flight muscles. Associated with the premigratory preparation is an increased nocturnal activity or nocturnal restlessness, known as "Zugunruhe." In captivity, "Zugunruhe" may have a directional component which reflects the true direction of the intended migration. During captivity, this nocturnal activity can be maintained for the entire length of the migratory season. Migration begins once the intrinsic (physiological and instinctive) and extrinsic (environmental) conditions are appropriate. In some instances, very large numbers of birds will begin to migrate simultaneously resulting in the early morning appearance of large concentrations of birds in certain locations.

The sites selected for the SPS rectenna and the power associated with the microwave beams could prove to have serious deleterious effects on large numbers of migrating birds if microwaves disrupt the ability of the birds to orient properly. In addition if microwaves disrupt nocturnal restlessness than the ability of the birds to show further orientation might be affected. These experiments were designed to provide data that would be used in answering these questions.

Emlen and Emlen (1966) described procedures for evaluating the orientation behavior of small avian migrants. These procedures were adapted in this study to determine the response of birds as they encounter an SPS microwave field in the middle of a migratory flight.

Only those mechanisms used for maintaining directionality therefore, are expected to be susceptible to alteration from microwave exposure.

The research was designed to answer the following questions.

1) Does exposure to microwaves influence the ability of a bird to maintain normal directional movements during migration?

2) Is the normal direction or orientation altered by continuous exposure to microwaves?

3) Is the chosen direction seasonally appropriate?

4) Is the strength of the directional behavior impaired (i.e., are movements from birds that are exhibiting significant non-random activity dispersed around the chosen direction when under exposure to microwaves)?

5) Does exposure to microwaves impair premigratory nocturnal restlessness?

4.2.2 Methods and Materials

The procedures developed by Emlen and Emlen (1966) involve use of a simple cage to study avian orientation. The "Emlen cage" consists of an inverted cone made of polystyrene (for microwave transparency) lined with blotting paper. The narrow base to the cage is centered around an ink pad while the top of the cage is covered by a transparent material, usually plastic hardware cloth. The caged bird therefore has a clear view of the night sky and will leave an ink footprint on the blotting paper each time it makes an attempt to escape. This record of the bird's activity is used to provide data on the directional preference of that bird.

4.2.3 Methods for Determining Directionality

At the conclusion of each test, the paper cone is divided into sixteen equal sectors (n=16) measuring 22.5 degrees (a_1, a_2, ... a_{16}). Each sector is then compared to a set of reference sectors provided by Emlen and Emlen (1966) and assigned a numeric value as a relative measure of the magnitude of activity. Darker sectors represent greater concentrations of footprints and therefore represent regions around the cone of greater movement or activity. The total of these values is the activity index (Ni) for a given bird. A large value of (Ni) represents a relatively greater level of activity during a particular test by the test animal. The cone is then analyzed as a series of vectors originating at the midpoint of a circle. The activity value assigned to the sector containing the greatest concentration of footprints becomes the longest vector, and is plotted as the radius of the circle. All other vectors become relative to this length.

The mean vector for each test is calculated by:

$$X = \frac{\sum_{i=1}^{n} \cos a_i}{N}$$

and

$$Y = \frac{\sum_{i=1}^{n} \sin a_i}{N}$$

The length of the mean vector (r) is determined by:

$$r = \sqrt{X^2 + Y^2}$$

Its mean direction ($\bar{a}$) is calculated by:

$$\cos \bar{a} = \frac{X}{r}$$

$$\sin \bar{a} = \frac{Y}{r}$$

The standard deviation for a circular distribution is termed its angular·

dispersion (s) (in degrees) is calculated by:

$$s = \sqrt{- 4.60517 \log r} \left(\frac{180}{\pi} \right)$$

The value for the length of the mean vector is a measure of the concentration of the bird's activity. A fundamental question about the bird's behavior is whether that activity is randomly distributed throughout the cage or significantly concentrated in one direction, i.e., non-random orientation. The Rayleigh-test is determined as:

$$z = nr^2$$

where (z) gives the critical values for a non-random distribution.

4.2.4 Exposure Conditions

Experiments were conducted in a small field surrounded by woodland in Manomet, Plymouth County, Massachusetts (41° 53'12"N and 70° 33'32"W). The site used is approximately seventy miles southeast of Boston. Artificial sky glow, which can seriously distort a bird's orientation, was determined to be minimal or completely absent. The inaccessibility of our site to humans kept disturbance to a minimum.

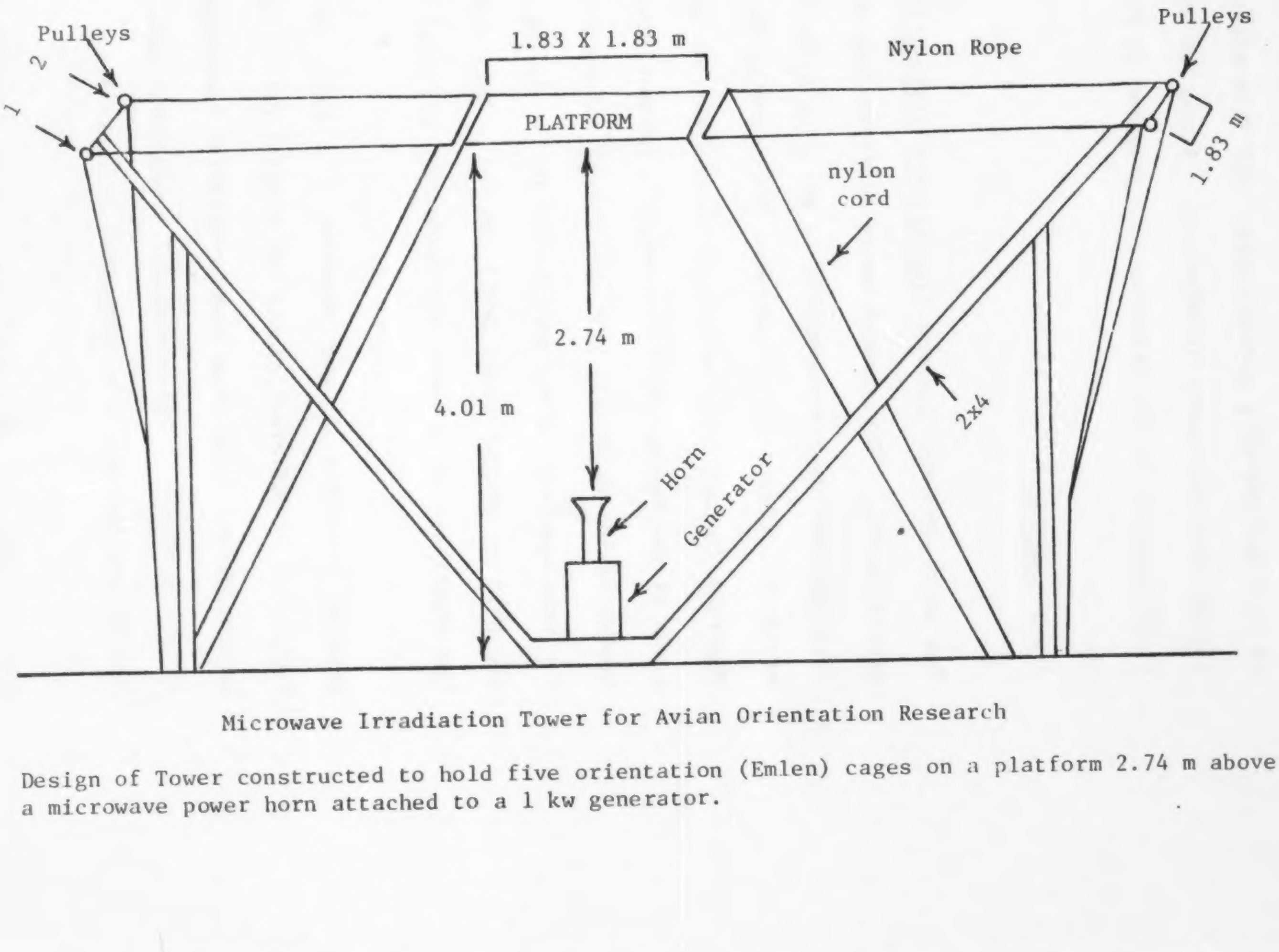
Once the optimum microwave field and the corresponding subject-to-power horn distance were determined, towers used to support the irradiated (treatment) and control cages were constructed. Each tower was designed to support a square microwave transparent platform which measured 1.82 by 1.82

meters on which five orientation cages could be raised to a position 2.74 meters above the irradiating horn (Figure 4-2). Since the power horn was mounted on the generator to give a combined horn-generator height of 1.27 m above the ground, it was necessary to suspend the platform 4.01 meters above the ground.

The platform consisted of a 5.0 cm thick polystyrene slab positioned on a frame made of polyvinyl chloride (PVC) tubing 3.8 cm in diameter. In the irradiation position, the platform was supported by nylon cords stretched to "T" shaped wooden supports. To prevent microwave reflections from the wooden supports, the support members were placed at an angle 45 degrees from the central position where the generator was located. Pulleys were attached to the four ends of the two crosspieces at the ends of the "T." The platforms were raised to an irradiation position by pulling on nylon ropes attached to the platform. The four corners of the frame were then secured to the ground with four lightly stretched nylon cords.

Emlen cages were fabricated using microwave transparent materials. Polystyrene board was cut and formed into a cone with a 15 cm diameter base, a 64 cm diameter top and a 15 cm depth above which a 9 cm rim was constructed. This design effectively raised the bird's view above the horizon in order to eliminate any possible disturbances due to visible landmarks (such as treetops) or artificial sky glow which might be encountered during experimentation. When experiments began the cages were mounted on the polystyrene platform, raised onto the tower, and secured in place with the nylon cord.

FIGURE 4-2


Pulleys
2
1
1.83 X 1.83 m
PLATFORM
Nylon Rope
Pulleys
1.83 m
nylon
cord
2.74 m
4.01 m
2x4
Horn
Generator

Microwave Irradiation Tower for Avian Orientation Research

Design of Tower constructed to hold five orientation (Emlen) cages on a platform 2.74 m above a microwave power horn attached to a 1 kw generator.

A Cober 1 kW portable microwave generator was employed as the power source. The resultant microwave field located 2.74 m above the generating horn provided a 23 mW/cm^2 exposure to a central Emlen cage, and 6.8 mW/cm^2 exposure to four peripherally placed cages. All five cages on the control tower received zero microwave irradiation. A map of the energy density of the field measured in the laboratory is provided in Figure 4-3.

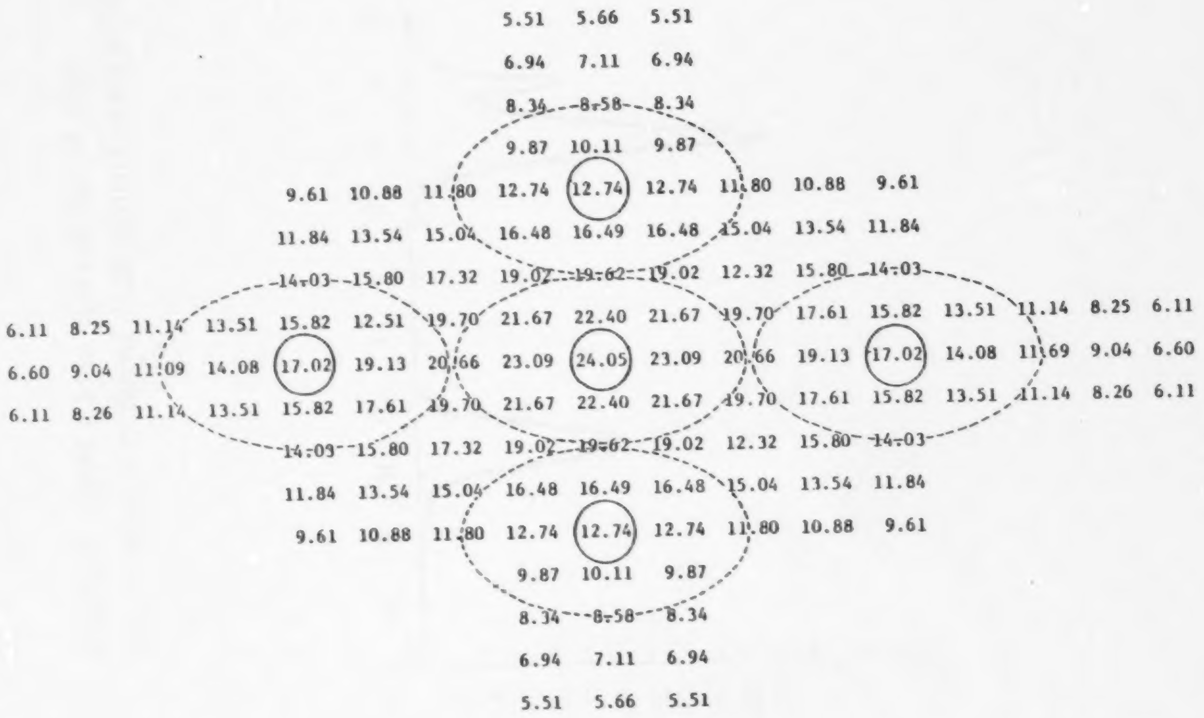
4.2.5 Subjects

The White-throated Sparrow (*Zonotrichia albicollis*) served as the experimental animal. This common North American species is a nocturnal migrant that has been used successfully in previous avian migration and orientation research. Figure 4-4 illustrates the seasonal movements of White-throated Sparrows through southeastern Massachusetts as determined by banding records at the Manomet Bird Observatory, Manomet, Massachusetts. The experimental period coincided with the normal autumn peak of migratory activity for this species. Birds were caught in the Spring of 1980 during migration and held in outdoor cages until the Fall. This insured that all birds had the experience of at least one successful previous autumn migration.

Between September 26 and November 13, 1980, 45 individual birds were studied on 17 different nights for a total of 140 tests. Eighty four tests were conducted under sham (non-irradiated) conditions; 46 at 6.8 mW/cm^2 and 12 at 23 mW/cm^2. Meteorological conditions were recorded each night of testing and the data are summarized in Table 4-4.

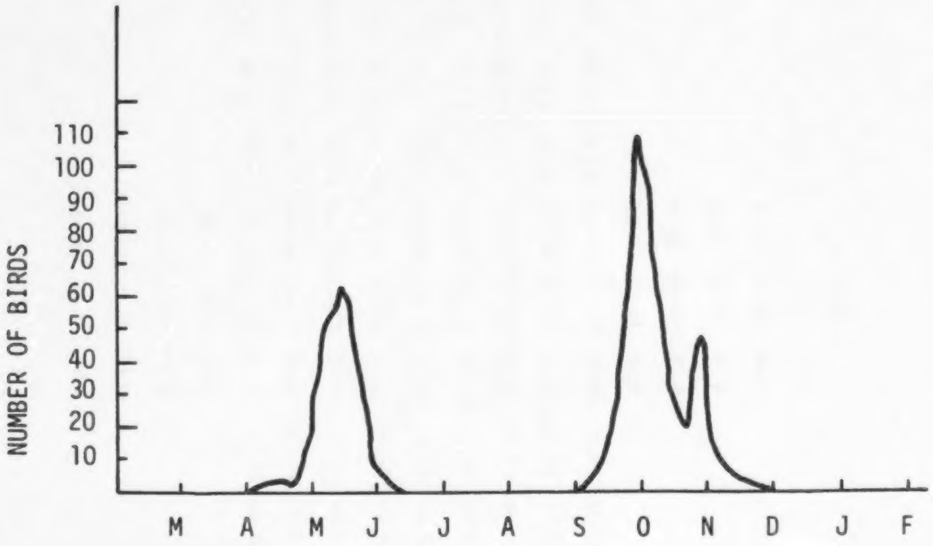
Wherever possible, each bird was exposed to microwaves and sham treated on

Figure 4-3


5.51 5.66 5.51
6.94 7.11 6.94
8.34 8.58 8.34
9.87 10.11 9.87
9.61 10.88 11.80 12.74 12.74 12.74 11.80 10.88 9.61
11.84 13.54 15.04 16.48 16.49 16.48 15.04 13.54 11.84
14.03 15.80 17.32 19.02 19.62 19.02 12.32 15.80 14.03
6.11 8.25 11.14 13.51 15.82 12.51 19.70 21.67 22.40 21.67 19.70 17.61 15.82 13.51 11.14 8.25 6.11
6.60 9.04 11.09 14.08 17.02 19.13 20.66 23.09 24.05 23.09 20.66 19.13 17.02 14.08 11.69 9.04 6.60
6.11 8.26 11.14 13.51 15.82 17.61 19.70 21.67 22.40 21.67 19.70 17.61 15.82 13.51 11.14 8.26 6.11
14.03 15.80 17.32 19.02 19.62 19.02 12.32 15.80 14.03
11.84 13.54 15.04 16.48 16.49 16.48 15.04 13.54 11.84
9.61 10.88 11.80 12.74 12.74 12.74 11.80 10.88 9.61
9.87 10.11 9.87
8.34 8.58 8.34
6.94 7.11 6.94
5.51 5.66 5.51

Map of the microwave power density field (measured in the laboratory) in which 5 orientation (Emlen) cages are irradiated. Microwave power density is depicted in units of mW/cm^2. The circumferences of the bottom of each cone shaped cage and the outside circumference of each cage are illustrated with solid and dashed lines, respectively.

The outside circumferences of the cages are actually circular but are depicted as elipses for ease of illustration.



WHITE-THROATED SPARROWS (ZONOTRICHIA ALBICOLLIS)
BANDED AT MANOMET BIRD OBSERVATORY IN 1978.

FIGURE 4-4

TABLE 4-4. METEROLOGICAL CONDITIONS DURING ORIENTATION EXPERIMENTS

Date (1980)	Ambient Temperature (^{o}C)[1]	Cloud Cover[2]	Moon Phase[3]	Wind Direction	Wind Speed[4]
9/26	-	0	0	NNW	8-25
9/29	10.0	0	0	SSE	11-16
10/1	12.8	100 (fog)	0	0	
10/8	15.6	20	0	SSW	12-16
10/9	12.8	0	0	NNW	0-8
10/10	8.3	0	0	SW	6
10/15	9.4	100	0	SW	0
10/22	8.3	5	F-1	WNW	12
10/23	6.1	20	F	NNW	10
10/27	7.2	0	0	-	0-8
10/29	5.0	0	0	NW	2-4
10/30	3.3	0	0	0	
11/2	4.4	0	0	NW	0-8
11/5	2.8	0	0	W	13 (gusts)
11/6	3.3	20	0	SW	8
11/7	CANCELLED				
11/13	8.9	100	0	NW	3-6

---

[1] Recorded at the beginning of each trial

[2] % of sky obscured by cloudcover

[3] 0 = no moon visible in sky; F = Full moon; F-1 = night before Full moon

[4] Km/h

[5] - undetermined

alternate nights. This approach was not always possible due to inclement weather and the lack of suitable behavior by the birds. Birds chosen for repeat experimentation were those that showed successful directional behavior or significant nocturnal activity during sham irradiated conditions. Consequently, inactive birds were rejected after only one trial while successful birds were retained and reused. After completion of tests, the distribution of footprints on the paper cones contained within the Emlen cages were analyzed.

4.2.6 Procedure

Each bird was used either as a control (sham) without microwave exposure or exposed at levels of 6.8 mW/cm^2 or 23 mW/cm^2. Upon conclusion of our experiments we discovered that we could divide each night into one of two conditions of cloudcover; nights with 100% cloudcover, which we designated "cloudy", and nights with 20% cloudcover or less, which we called "clear." During the actual test period, the night skies were either "clear" or totally overcast (Table 4-4).

Emlen cages, containing birds, were placed on the exposure platforms thirty minutes after sunset. The actual experimentation, however, did not begin until the sky was completely dark or approximately one hour after sunset. Consequently, the birds had a thirty minute opportunity to view residual light from the setting sun as well as the emergent star patterns on clear nights in order to establish an orientation Even on cloudy nights, residual light from the setting sun could provide a visible landmark or cue on which the birds could orient. In all cases, birds had an opportunity to make a directional choice before experimentation began. Polyethylene sheets were placed over the ink pads to prevent the recording of activity before the beginning of the experiment. Each experiment lasted a total of ninety minutes.

4.2.7 Results and Discussion

Question One: Does exposure to microwaves influence the ability of a bird to maintain directional movements during migration?

To determine if microwave exposure influenced the ability of birds to maintain their directional capabilities during periods of normal migration, we compared the frequency distributions of randomly oriented behavior and non-randomly oriented (or directional) behavior on clear and cloudy nights for each of the three microwave exposure conditions. Chi-square analyses were performed on the data to determine the significance of the treatments.

The total activity index (T.A.I), the length of the mean vector (r), its direction in degrees (theta), the angular dispersion in degrees (s) and the probability of significant directionality (p) for each of the 129 paper cones from Emlen cages are listed in Table 4-5 From these data the frequencies of occurrerce of directional behavior among the control and the two microwave dosages (6.8 and 23 mW/cm^2) on clear and also on cloudy nights were compared using the Chi-square analysis (Table 4-6).

Key to Table 4-5

Subject	Each bird is identified by a unique combination of color bands placed on the bird's legs. An example is B-Lg which represents a black band on the left leg and a light green band on the right leg.
T	The experimental conditions used for each test: C is a control trial; E7 and E23 indicate experimental tests at 7 and 23 mW/cm^2 respectively.
T.A.I.	The Total Activity Index is the cumulative score for the activity values of the 16 sectors for each test cone. This represents the total activity exhibited by a bird during a single test.
r	The paper cone for a single test is divided into 16 x 22.5 degree sectors, each of which has its concentration of footprints described by a vector. The mean vector for the cone has a value for its length which is "r."
ϕ	The azimuth (degrees) of the mean vector of a paper cone where 360 = north; 90 = east; 180 = south; 270 = west.
s	The angular dispersion around the mean vector which describes the variability of the footprint concentrations on a single cone.

p	The probability factor. The length of the mean vector (r) can be used to test for nonrandom concentrations of activity using the Rayleigh Test. The probability levels for randomness are provided in this final column. A probability less than or equal to 0.05 would represent a significantly nonrandom orientation by a bird on a single test.

TABLE 4-5. ORIENTATION BEHAVIOR OF WHITE-THROATED SPARROWS

Subject	T	Date	T.A.I.	r	φ	s	P Values ≤ .05
B-Lg	C	9/26	10	.614	131.6	50.3	.02
	C	9/29	9	.503	19.7	57.1	
	E7	10/1	19	.421	29.7	61.6	.05
	C	10/9	12	.205	50.5	72.2	
	C	10/27	6	.789	258.7	37.1	.02
	E7	10/30	13	.495	360.0	57.5	.05
	C	11/2	6	.411	161.2	62.1	
	E7	11/6	17	.271	38.6	69.1	
P-P	E7	9/29	20	.349	127.7	65.3	
	E7	10/1	67	.150	39.4	74.7	
	C	10/8	107	.187	337.7	73.0	
	C	10/9	64	.120	209.9	75.9	
	C	10/27	85	.216	281.0	71.7	
	E7	10/30	34	.215	204.2	71.7	
	C	11/5	98	.078	180.0	77.8	
-M	C	10/9	5	.200	247.5	72.5	
	C	11/13	12	.547	285.2	54.5	.05
Lb-Lg	C	9/26	10	.884	85.4	27.5	.001
	E7	10/27	19	.497	337.8	57.4	.01
	C	10/30	12	.844	315.9	32.0	.001
Pg-	C	10/22	23	.129	249.6	75.6	
	E7	10/23	29	.267	191.6	69.4	
	C	10/29	15	.289	71.4	68.3	
	E7	11/2	23	.395	225.6	63.1	.05
W-Pg	C	10/15	45	.257	126.5	69.9	
	E7	10/29	3	.949	225.0	18.3	
	E7	11/2	24	.109	225.0	76.5	
	C	11/6	22	.475	324.8	58.7	.01
Lb-P	C	10/22	11	.475	263.1	58.7	
	E7	10/23	33	.152	103.5	74.6	
	C	10/29	31	.501	84.6	57.2	.001
	E7	11/2	18	.652	354.7	47.8	.001
	E7	11/6	51	.646	26.4	48.2	.001
Lb-W	E23	10/10	28	.170	60.9	73.8	
	C	10/15	32	.129	207.8	75.6	
	E23	10/29	24	.219	22.5	71.6	
	C	11/2	5	.852	45.0	34.1	

TABLE 4-5. ORIENTATION BEHAVIOR OF WHITE-THROATED SPARROWS (CONTINUED)

Subject	T	Date	T.A.I.	r	ϕ	s	P Values ≤ .05
Pg-Y	C	10/22	23	.312	278.1	67.2	
	E7	10/23	20	.205	110.2	72.3	
	E7	10/29	28	.497	301.8	57.5	.001
	C	11/2	4	.906	101.3	24.8	
-Pg	E7	11/13	7	.563	356.9	53.5	
O-Y	C	10/9	27	.185	336.1	73.1	
	E7	10/27	78	.210	228.2	72.0	.05
	C	10/30	67	.215	337.1	71.8	.05
	E7	11/13	11	.156	207.2	74.5	
W-	E7	10/10	13	.178	73.0	73.5	
	C	10/15	17	.500	58.7	57.3	.02
	E7	10/22	16	.633	201.6	49.1	.001
	C	10/23	11	.419	149.5	61.7	
-B	E23	9/29	10	.139	96.6	75.2	
	C	10/8	18	.458	285.9	59.7	.05
	C	10/9	16	.112	114.4	76.4	
B-M	C	10/9	20	.599	24.3	51.3	.001
	E7	10/27	34	.316	116.2	67.0	.05
	C	10/30	13	.365	286.9	64.6	
	C	11/5	7	.211	335.2	72.0	
	E7	11/13	13	.185	193.5	73.2	
M-M	C	10/22	11	.241	285.5	70.6	
	E7	10/23	9	.316	337.5	67.0	
	E7	10/29	3	.790	350.7	37.1	
	E7	11/6	10	.641	82.2	48.6	.02
-B/G	C	10/9	29	.251	201.2	70.1	
	C	10/27	24	.242	243.9	70.5	
	E7	10/30	26	.504	23.8	57.1	.002
	C	11/2	10	.788	116.4	37.3	.001
-Y/B	E7	10/15	19	.701	38.0	44.3	.001
	C	11/2	14	.578	189.3	52.7	.01
DB-Lg	C	9/29	19	.517	32.4	56.3	.005
	E7	10/1	17	.451	194.8	60.0	.05
	C	10/8	7	.393	193.9	51.7	
	C	10/9	10	.834	96.2	30.9	.001
	E23	11/2	21	.385	208.2	52.2	.001
	C	11/5	6	.709	281.3	37.2	.02

TABLE 4-5. ORIENTATION BEHAVIOR OF WHITE-THROATED SPARROWS (CONTINUED)

Subject	T	Date	T.A.I.	r	ϕ	s	P Values ≤ .05
M-B	E7	10/22	43	.137	85.7	75.3	
	C	10/23	31	.283	81.2	68.6	
	E7	11/6	28	.184	331.4	73.2	
	C	11/13	19	.111	219.1	76.4	
B-R	C	9/26	15	.464	115.6	59.3	.05
	C	9/29	23	.516	304.9	56.4	.002
-M/Y	C	10/10	10	.774	81.9	38.6	.002
	C	10/15	15	.263	115.7	69.6	
-P/Pg	E7	10/15	10	.453	238.9	59.9	
	C	11/6	18	.289	243.3	68.3	
Lg/Db-R	E7	9/29	11	.509	309.5	56.9	
M/P-	C	10/10	23	.197	164.4	72.6	
Pg/W-	C	10/10	36	.136	196.5	75.3	
G/W-M	E7	10/10	15	.190	337.5	72.9	
Lb/W	E7	10/10	11	.149	250.6	74.8	
B/W-Lg	C	10/10	15	.365	46.0	64.5	
Cs-P	C	10/1	24	.449	100.4	60.2	.01
B-B	C	10/1	16	.373	86.4	64.2	
Cs-B	C	10/1	-	-	-	-	
B-P	C	10/1	-	-	-	-	
-Y	C	10/9	11	.388	22.5	63.4	
-Lb/Y	E7	10/29	17	.218	230.9	71.7	
Y/Pg	E7	10/15	30	.171	142.9	73.8	

TABLE 4.5. ORIENTATION BEHAVIOR OF WHITE-THROATED SPARROWS (CONTINUED)

Subject	T	Date	T.A.I.	r	ϕ	s	P Values < .05
-Y/Lb	C	10/10	13	.281	42.5	67.7	
	C	10/22	15	.465	187.6	59.3	.05
	E23	10/23	20	.441	221.0	60.6	.02
	C	11/6	48	.256	315.8	69.9	.05
Pg-Lb	E23	10/15	7	.799	28.1	36.3	.01
	E7	10/22	9	.774	183.2	38.6	.005
	C	10/23	30	.251	46.3	70.1	.001
Pg/Y-	E7	10/10	8	.302	30.2	67.7	
	E7	10/22	29	.173	202.5	73.7	
	C	10/23	23	.124	135.0	75.9	
	C	11/6	8	.414	358.1	62.1	
	C	11/13	19	.351	42.2	65.3	
Pg/Lb-	E7	10/15	12	.134	129.1	75.4	
	C	11/6	24	.284	319.6	68.6	
	E7	11/13	16	.361	150.5	64.8	
R-Lg	C	9/26	30	.304	307.1	67.6	
	C	9/29	60	.259	302.0	69.8	.02
	E23	10/1	34	.066	108.2	78.3	
R-Lb	C	9/29	23	.164	345.8	74.1	
-Lg	E23	10/27	11	.655	9.4	47.6	.01
	C	10/30	15	.451	39.0	60.0	.05
	C	11/13	12	.716	335.6	43.2	.002
Lb-B	C	10/9	11	.740	126.2	41.3	.002
	E7	10/27	25	.323	54.9	66.7	
	C	10/30	12	.587	313.6	52.1	.02
Db-	E7	9/29	26	.163	171.7	74.1	
	E7	10/1	22	.565	42.8	53.4	.001
	C	10/8	18	.763	37.8	39.4	.001
	E23	10/30	13	.333	212.7	66.2	
	C	11/5	36	.096	348.7	77.0	
W-B/B	C	10/15	19	.529	313.7	55.6	.005
	E23	10/22	8	.140	303.7	75.2	
	C	10/23	21	.585	351.3	52.2	.001

TABLE 4-5. ORIENTATION BEHAVIOR OF WHITE-THROATED SPARROWS (CONTINUED)

Subject	T	Date	T.A.I.	r	ϕ	s	P Values ≤ .05
-M	C	10/27	0	-	-	-	
	E7	10/30	4	-	-	-	
-Pg	C	10/29	0	-	-	-	
-B	E23	11/6	0	-	-	-	
	C	11/13	0	-	-	-	
M-M	C	11/2	0	-	-	-	
-B/G	E7	9/29	0	-	-	-	
-7/Lb	E23	11/13	0	-	-	-	
R-Lb	C	9/26	0	-	-	-	
-Lg	C	10/08	0	-	-	-	

Examination of data in Table 4-6 reveals that the presence of randomly and non-randomly oriented behavior is independent of microwave dosage and cloud cover. We can therefore conclude that microwave exposure at the power densities used does not affect the ability of birds to show directional behavior when placed in Emlen cages. It is particularly interesting to note that cloudcover did not alter the presence or absence of directionality before or during exposure to microwaves. Approximately one third of all test birds showed directional behavior regardless of cloudcover and microwave exposure.

Question Two: Is the chosen direction of orientation altered by exposure to microwaves?

To determine whether microwave irradiation caused changes in the directional preference of the orientation behavior, we compared the mean azimuths of several circular distributions grouped by microwave dosage and cloudcover. Since microwave irradiation did not affect the frequency of random orientation behavior between treated and non-treated birds, we conclude that the demonstration of random activity was based on factors not related to microwaves. Therefore, only those birds which exhibited non-random behavior (as determined by the Rayleigh z-test) were used for comparison. Analyses were performed using statistical procedures outlined by Batschelet (1972 and 1978) and Zar (1974).

The mean orientation vectors: (1) all nights of testing, (2) nights with clear skies, and (3) nights with cloudy skies, are illustrated in Figure 4 5. Non-irradiated birds ($0 mW/cm^2$) show a significant non-random

TABLE 4-6. RESULTS OF CHI-SQUARE TESTS* ON THE DISTRIBUTION OF RANDOM AND NON-RANDOM BEHAVIOR

CLOUDY CONDITIONS

Orientation	Microwave Exposure (mW/cm^2)		
	0	6.8	23
Random	10	8	2
Non-random	6	3	1

$X^2 = .25$ df = 2 $p > .8$ $n = 30$

CLEAR CONDITIONS

Orientation	Microwave Exposure (mW/cm^2)		
	0	6.8	23
Random	41	22	6
Non-random	24	14	3

$X^2 = .30$ df = 2 $p > .8$ $n = 110$

TOTAL CONDITIONS

Orientation	Microwave Exposure (mW/cm^2)		
	0	6.8	23
Random	51	30	8
Non-random	30	17	4

$X^2 = .44$ df = 2 $p > .8$ $n = 140$

*All data were analyzed as 3x2 chi-square contingency tables, df=2.

directional choice to the north (Anje Circular One-Sample Test; p=0.02). Microwave treated birds at 6.8 and 23 mW/cm^2 each had northwest directional preferences, however, these distributions are not statistically different from random. A comparison of sample mean angles using the Watson μ^2 Two Sample Test revealed that they are oriented in directions which do not represent different populations (p>0.5).

On nights with clear skies, the non-treated group had a significant non-random directional preference to the north (p=0.075). The microwave treated birds (6.8 plus 23 mW/cm^2 combined) also had a northerly directional preference but the distribution was not statistically different from random (p=0.5). This overall northerly directional preference was maintained on nights with cloudy skies although the distribution of mean angles for the non-treated group was random. The sample size of the microwave treated group was too small to analyze for non-randomness. A comparison of treated and non-treated distributions for both cloudcover samples were not significantly different (Watson μ^2; p>0.5).

Question Three: Is the chosen direction seasonally appropriate?

The value for theta (Table 4-7) is the compass direction of the mean azimuth for each circular distribution with 360 degrees being north; 180 degrees being south; 90 degrees being east and 270 degrees being west. These mean directions are shown diagramatically in Figure 4-5. The arrows are used to indicate the mean direction for each individual exposure subgroup (0, 6.8 and 23 mW/cm^2).

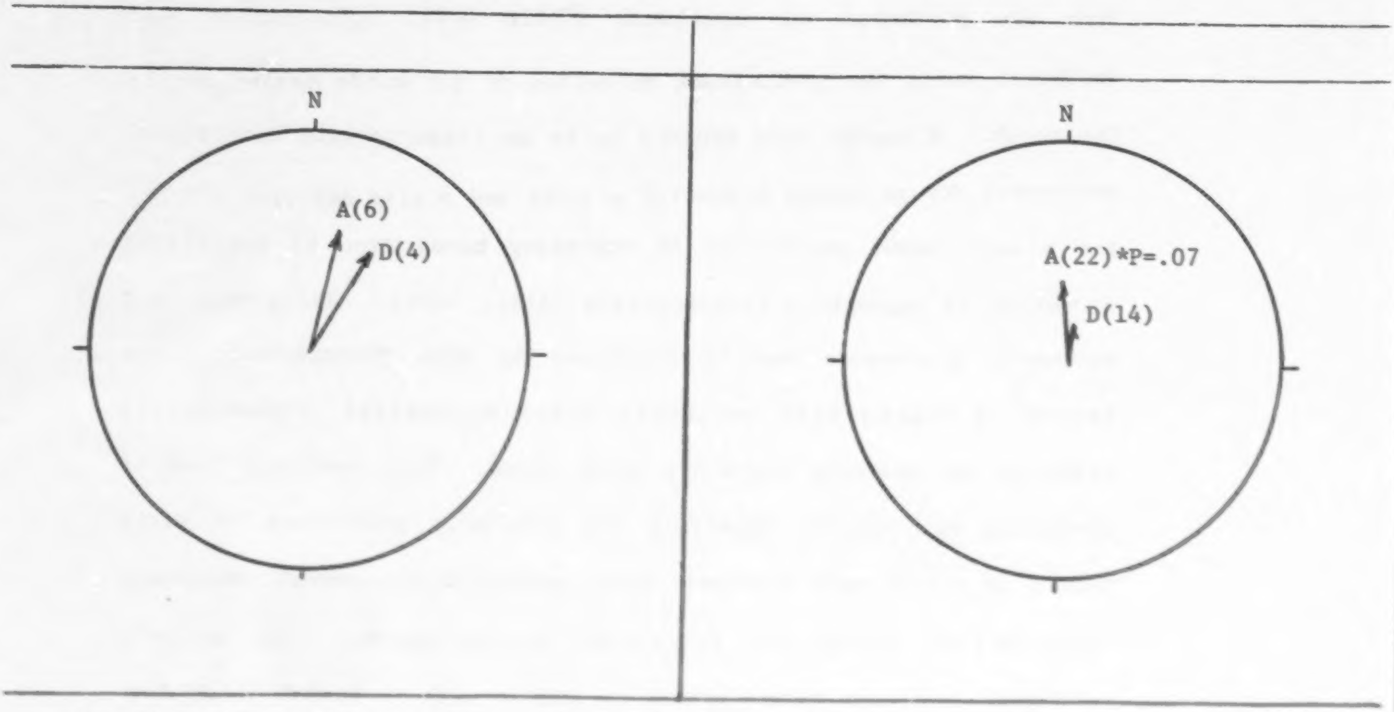
TABLE 4-7. RESULTS OF THE WATSON U^2 TWO SAMPLE TEST FOR COMPARING CIRCULAR DISTRIBUTIONS OF SUBGROUPS SEPARATED BY CLOUDCOVER AND MICROWAVE DOSAGE

Test Conditions	Microwave Dosage (mW/cm^2)	n	Theta (degrees)	U^2	p
Non-Randomly Oriented Birds Only					
Clear Nights (w/o moon)	0*	22	356°	.0640	p>.5
	6.8 & 23	14	1°		
Cloudy Nights	0	6	14°	.0875	p>.5
	6.8 & 23	4	32°		
All Nights	0*	30	358°	.1013	p>.2
	6.8	17	310°		
	0	30	358°	.0784	p>.2
	23	4	292°		
	0	30	358°	.1124	p>.2
	6.8 & 23	21	298°		
	6.8	17	310°	.0712	p>.2
	23	4	292°		

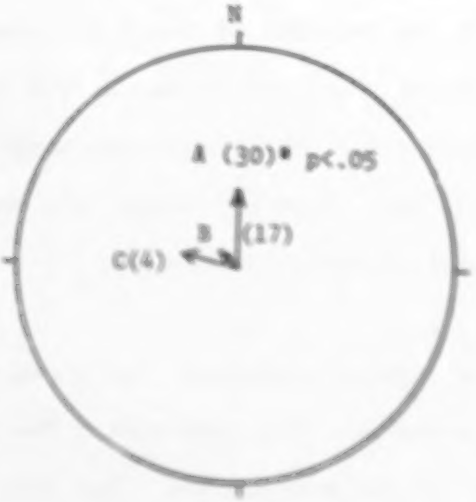
0-360 = north; 90 = east; 180 = south; 270 = west
n = number of experiments
* = significant preferred direction using Anje "circular one-sample test"; on clear nights p=.075; on all nights p=.02.

FIGURE 4-5

Mean Directions Exhibited by Groups of Birds Under Various Conditions of Cloudcover and Microwave Exposure (6.8; 23 mW/cm^2)



Results from Clear and Cloudy Skies (Pooled) for 6.8 and for 23 mW/cm^2



Treat.	Power Density mW/cm^2
A	0
B	6.8
C	23
D	6.8 and 23 (pooled)

* = Non-random Distribution
( ) = N = number of Birds Tested [experiments]

The predominant wind directions during the autumn test period were from the northwest and southwest (Table 4-4). On nights with southwest winds the predominant direction of all birds tested was to the north. Although this appears to be an inappropriate directional preference for an autumn migration passive and active downwind flights are a well known phenomenon of migrating birds even if the flight direction is seasonally inappropriate (Albe, 1974). The predominant northerly preference may be explained by this phenomenon. Birds tested on nights with northwest winds maintained predominantly westerly and easterly migratory preferences. This resultant lack of southerly mean angles magnifies the northerly preference of birds tested on nights with southwest winds producing the overall seemingly inappropriate directional preference to the north. The westerly component from some birds tested on nights with northwest winds does not lend itself to easy interpretation.

Question Four: Is the strength of the directional behavior impaired i.e., are movements from birds which are exhibiting significant non-random activity more or less dispersed around the chosen direction when exposed to microwaves?

The value (s), or angular dispersion, is a measure of the spread of the bird"s activity around the mean direction. The larger the value for (s), the less precise is the orientation. The only subgroups analyzed were those that exhibited significantly non-random orientation since analysis of randomly oriented birds would merely be an analysis of an already significantly dispersed activity pattern. The data were grouped by cloudcover and then ranked by level of microwave irradiation and angular dispersion. A Spearman Rank correlation coefficient was calculated and used to determine whether microwave dosage affected the concentration of activity of individual birds exhibiting strong directional behavior.

Table 4-8 presents the results of this analysis comparing angular dispersion with microwave dosage on clear and cloudy nights of testing. There was no association between these variables (on all nights of testing $p = 0.43$; under cloudy skies $p = 0.86$; and under clear skies $p = 0.40$). We can conclude from these results that microwave exposures at 6.8 and 23 mW/cm^2 do not increase or decrease the dispersion of activity of non-randomly oriented birds tesed in Emlen cages.

Question Five: Does exposure to microwaves impair premigratory nocturnal restlessness?

Nocturnal restlessness that is associated with migration by a bird is measurable. It is possible therefore to examine not only the quality of the bird's behavior during a test but also the quantity of the behavior. If the microwaves are assumed to act as a sedative in birds or as an inducement to hyperactivity, this effect could distort the quality of an activity that appears to be related to migration. The test subjects were grouped as before into "all birds tesed" and "non-randomly oriented birds" and subdivided by percent cloudcover. Microwave exposure levels were ranked with levels of activity, and a Spearman Rank Correlation Coefficient calculated to determine the degree of association.

TABLE 4-8. RESULTS OF THE SPEARMAN RANK CORRELATION COMPARING ANGULAR DISPERSION WITH MICROWAVE EXPOSURE

Non-randomly Oriented Birds

Test Conditions	n	r_s	p =
Clear Conditions	41	.14	.40
Cloudy Conditions	10	-.06	.86
All Conditions	51	.11	.43

Table 4-9 summarizes the results of these analyses. No correlation between the quantity of the bird's activity and microwave dosage was found under any conditions of cloudcover or grouping by demonstration of directional randomness. We can therefore conclude that at dosages of 6.8 and 23 mW/cm^2 acute premigratory restlessness is not impaired or enhanced.

4.2.8 Conclusion

In an attempt to conceptualize the results of this study we must consider the free flying bird. Our experiments were designed to examine the effects a microwave field might have on a bird's subsequent behavior and its capability to maintain an accurately aimed effective flight. We found no significant effects from microwaves on the activity of caged birds, their capacity to show non-random directional behavior, the dispersion of that activity around their mean directional choice and the specific directional preferences of sample distributions under different cloudcover conditions. However, the non-treated birds showed their movements to be non-randomly distributed on nights with clear skies and on all nights combined. The same distribution of microwave treated birds were found to be random. Therefore, while the mean angles, or preferred directions were the same, the microwave treated birds showed a greater dispersion of chosen directions around the mean. This is therefore a significant influence which can only be attributed to microwave exposure. Hence, we can conclude that although there was no significant change in directional preference by birds under exposure to microwaves at the power densities projected for use by the SPS, the increased dispersion of those treated birds represents an influence which must be considered as potentially hazardous to migratory birds.

TABLE 4-9. RESULTS OF THE SPEARMAN RANK CORRELATION COMPARING TOTAL ACTIVITY WITH MICROWAVE EXPOSURE

Test Conditions	n	r_s	p =
All Test Birds			
Clear Conditions	110	.0495	.607
Cloudy Conditions	30	-.1110	.558
All Conditions	140	.0210	.805
Non-randomly Oriented Test Birds			
Clear Conditions	41	.1238	.440
Cloudy Conditions	10	-.1589	.660
All Conditions	51	.0823	.565

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4.3 SOCIAL INTERACTIONS AND LETHALITY STUDIES

(October 1979 - April 1980)

4.3.1. Social Interactions

4.3.1.1 Introduction

The objective of this study was to assess the effects of acute microwave radiation on the behavior and position of birds within a flock dominance hierarchy.

The White-throated Sparrow (Zonotrichia albicollis) and the Dark-eyed Juncos (Junco hyemalis) both congregate naturally in small flocks in winter, most likely, to increase their feeding efficiency (Buskirk 1972; Krebs, 1973; Krebs, MacRoberts and Cullent, 1972) and/or for protection from predators (Dimon and Lazarus, 1974; Goldman, 1980; Hamilton, 1971; Lack, 1954; Lazarus, 1972; Short, 1961; Vine, 1971). Social hierarchies form within the flocks (Sabine, 1959; Ficken, Ficken, and Hailman, 1978) to reduce competition for essential resources (Balph, 1977).

4.3.1.2 Materials and Methods

White-throated Sparrows and Dark-eyed Juncos were captured from November 1979 through 10 January 1980 at Manomet Bird Observatory, Manomet, Massachusetts, using mist nets. Birds were color-banded for individual recognition and initially housed in a large outdoor aviary. On 12 December 1979, we began matching conspecifics for size, age, plumage darkness, and in the case of Juncos, eye color for the purpose of establishing uniform group composition (Ketterson and Nolan, 1976; Ketterson, 1979). When a full complement of six birds was reached, the group was placed into an aviary measuring 2.0 m x 1.5 m x 2.0 m. (Appendix A4.3-1.)

Initial observations over a period of two to three weeks provided basic flock structure data, the dominance order within the flock, and allowed the observer to become familiar with the birds' behavior patterns. During this period, we made observations for one or more 15 minute periods each day until we recorded an interaction matrix of at least five active encounters between each pair of birds. Encounters were classified as either active aggression or avoidance (Table 4-10). Active encounters included supplanting, attacking or chasing a subordinate. Avoidance encounters were more subtle in nature. They did not involve active chases but were primarily threat displays such as tail-up, head-forward, and bill-up postures. Subordinate individuals were identified as those birds that moved away in response to threats or attacks. We derived an intensity of response scale with the highest score of three being given for an active encounter in which one bird clearly chased another away from the feeding tray. After scaling and averaging (per 15 minutes) interactions between all pairs of birds (as shown in Table 4-11), we constructed dominance hierarchies. Reversals, found to be rare, were subtracted from dominant interactions. An example of the data and forms used are provided in Tables 4-11 and 4-12.

On 24 January 1980, exposure of birds to microwave radiation began. Irradiations were performed between 9:00 a.m. and 10:00 a.m Prior to the exposure, the selected cage was entered and all birds trapped and placed in individual cells of a holding box. Each bird was examined for injuries, weighed, and placed either in an exposure cage or a sham-irradiation cage.

TABLE 4-10. BEHAVIORAL SCALE USED IN EVALUATING THE INTENSITY OF AGONISTIC ENCOUNTERS

		Behavioral Score
Active Aggression:		
$A \gg B$	A actively chases B away from the feeding tray following in pursuit beyond the tray.	3
$A > B$	A moves towards B or pecks towards B with enough intensity to cause B to leave the feeding tray.	2
$A \geq B$	A moves towards or pecks at B but B is not forced to leave the feeding tray.	1
Avoidance:		
$A \sim B$	B avoids A, but remains on the feeding tray. Both birds continue to feed but B constantly moves away from A. A never makes an observable aggressive move to cause the avoidance by B.	1
$A \approx B$	B avoids A by leaving the tray without feeding. A never makes an observable aggressive move to cause the departure by B, but the avoidance (is seen) to be caused by presence of A.	2
Other:		
$A = B$	A and B are feeding on the tray together, not engaging in any interactions which suggest a hierarchy.	0
$A \parallel B$	B is sitting on the tray while A is feeding on the tray. The birds appear to be aware of each other yet no aggressive interactions occur. $A \parallel B$ differs from $A = B$ in that only one of the birds is feeding.	0

Table 4-11. Calculation of Aggression Level Between Two Birds Dominance
(Cage 1)

	Type and Incidence of Behaviorial Interaction (See Table 1)							
a) Dominance Actual Number	>>	>	≥	=	≃	~	||	
-R Dominant to W-O	1	41	13	10	17	6	0	
W-O Dominant to -R		1						
b) Weighted Score Used to Determine Intensity of Relationship in a)	3	2	1	0	1	2	0	
Dominant Score	3 +	82 +	13	+	17 +	12	=	127
Reversal Score (Subtracted)		2						− 2
								125

Total # of 15 Minute Periods = 35

Intensity of Aggression (-R Dominant to W-O) = 125/35 = 3.57 per 15 minutes

Table 4-12. **Dominance Hierarchy for Cage 1: White-throated Sparrows (Before Exposure)**

Raw Totals

	-R	W-O	DB-DB	LG-	DB-Y	Y/LB
-R		127[a]	64	69	46	34
W-O	2		50	59	28	77
DB-DB^{+}				33	28	16
LG-					19	60
DB-Y		1				34
Y/LB				2	2	2

Scaled Level of Aggression per 15 minutes

	-R	W-O	DB-DB	LG-	DB-Y	Y/LB
-R		3.57[a]	1.83	1.97	1.31	0.97
W-O			1.43	1.69	0.77	2.20
DB-DB				0.94	0.80	0.40
LG-					0.54	1.66
Y/LB						

Cage # 1

Dates 12/12/79 to 1/18/8

Total Time 525 minutes
(mins.)

Total Periods 35
(15 mins.)

---

[a] For calculations of Raw Totals and Scaled Level of Aggression see Table 2

The sham-irradiated birds were placed on blocks of anechoic material in an area well away from the exposure tower, but in a location easily viewed from the observation site. The birds to be irradiated were then placed beneath the horn in a location determined to produce the desired power density. During the early experiments, when a single bird from each flock was exposed, the cage was centered beneath the horn. When the change to a two-bird irradiation was made, the two cages were fastened together and the unit was placed with its long axis coincident with that of the horn and centered.

Exposure time was controlled with a digital timer, reading to 0.1 seconds. Three persons participated in the irradiation. One initiated the exposure cycle and provided time reference data to the observers. The first observer watched the irradiated birds from a short distance (ca. 4m) using close-focusing binoculars. This observer took notes on the bird's activities, receiving time data from the exposure controller to reference significant behavior. The second observer operated the motor driven camera while observing the bird through the camera. The camera was also located about 4 m from the cages and provided a full-frame image using a 210 mm telephoto lens. Although the first observer could have operated the camera via its remote-control cord, we chose to use two observers working simultaneously to minimize the chance of missing some transient behavioral reponse which might prove significant.

Although initial exposures were performed on the number three bird in the social order, we elected, after careful consideration, to use two birds from each flock, thus doubling the number of treated birds. Subsequently, we selected the second and fourth bird from each group. Thus, each irradiated bird was bracketed in the social order by at least one non-irradiated flock member.

4.3.1.3 Microwave Field Mapping

The microwave field from the 1 Kw generator at the Manomet Bird Observatory experimental site was mapped in order to determine the uniformity of the field to which the birds were exposed. Since the test subjects were not restrained, but are allowed to move freely within a cubical cage 15 cm on a side, it was critical to preclude the possibility of standing waves in the microwave field producing a significant power density variation within the exposure cages.

In order to perform the mapping, a 7/8" hole was drilled through the center of a block of anechoic material. The hole was sized to allow a friction-fit for the probe of the NARDA survey meter. Two rails were attached between the sides of the exposure tower on which the block could be rested, allowing movement in the horizontal plane. Index pointers were attached to the probe block, and matching calibration marks were laid out on the support rails. A 9 x 10 point grid with 2.54 cm point-to-point spacing was set up producing a 113 point field map. The probe tip was located 70 cm beneath the horn. This distance was chosen at the closest working distance used in the experimental exposures at Manomet, and thus representative of worst-case field uniformity.

Figure 4-6 shows the point-by-point field strength measurements normalized to unity. Also shown is the projection of the horn dimension onto the mapping plane. Note that the center of the radiation field is displaced about 5.7 cm from the center of the vertical projection of the horn. This confirms the observation made at the time of installation that the horn and waveguide were at a slight angle from the true vertical, calculated to be a 4.7° angular error, because of a tilt in the supporting tower.

Figure 4-7 shows the approximate power density contours at ± 5, 10, and 15 percent of the central value. Once again, the projection of the horn is shown, as is the outline of the restraint cage used for these exposures.

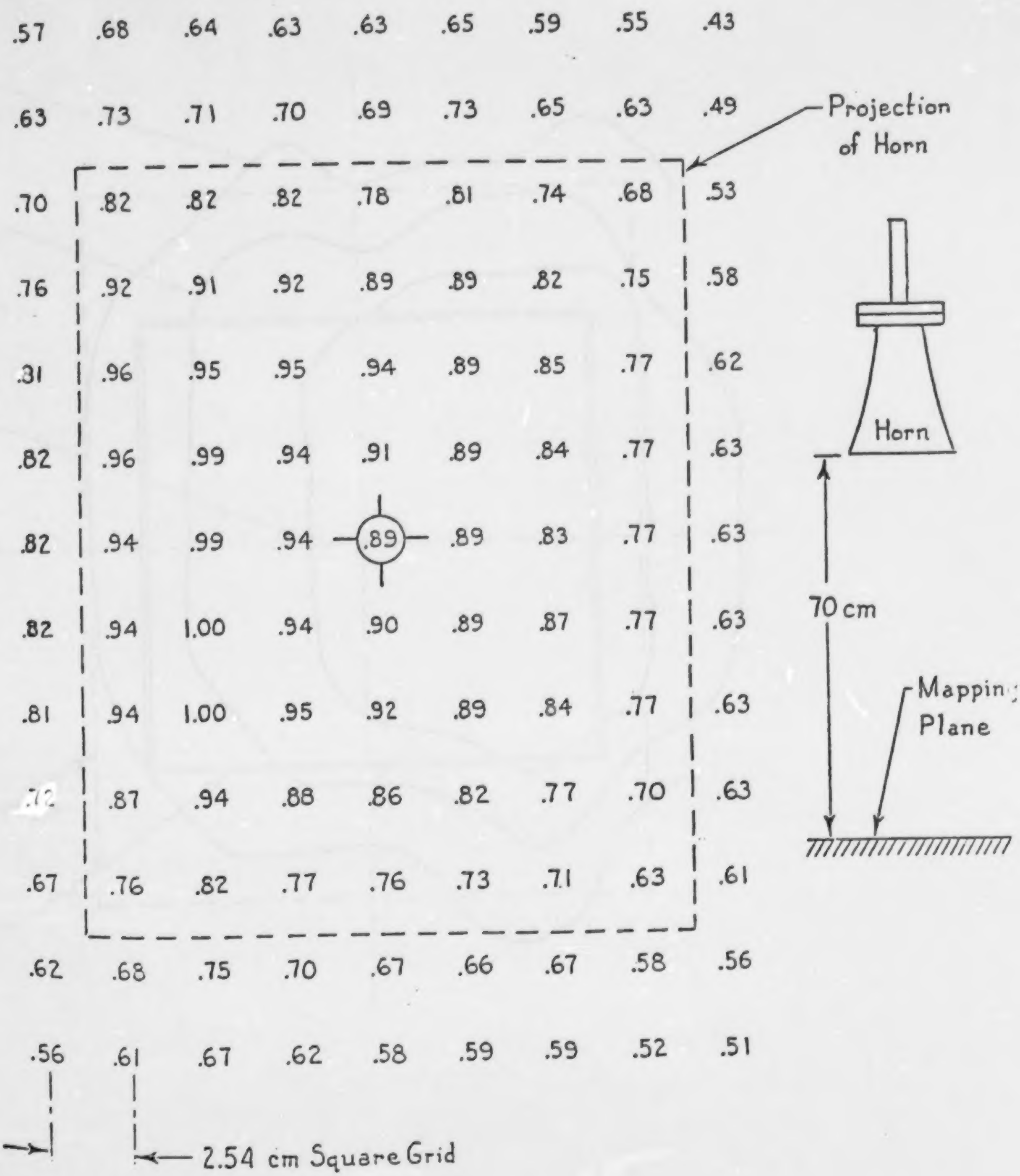
In addition to measuring the power density distribution, the amplitude modulation of the emitted radiation was determined. A condition of 100 percent modulation was found with an envelope pattern characteristic of one half wave, 60 Hz ripple. This was not an acceptable level of amplitude modulation but it could not be reduced to a level of 10% or less without major generator modification.

4.3.1.4 Results

Seventeen birds among twelve flocks containing six birds each were exposed to the four combinations of microwave density and duration along with three sham controls from two additional flocks as shown in Table 4-13 (Appendix A4.3-2).

FIGURE 4-6

POWER DENSITY MAP IN MEDIAN PLANE OF CAGE



.57	.68	.64	.63	.63	.65	.59	.55	.43
.63	.73	.71	.70	.69	.73	.65	.63	.49
.70	.82	.82	.82	.78	.81	.74	.68	.53
.76	.92	.91	.92	.89	.89	.82	.75	.58
.81	.96	.95	.95	.94	.89	.85	.77	.62
.82	.96	.99	.94	.91	.89	.84	.77	.63
.82	.94	.99	.94	.89	.89	.83	.77	.63
.82	.94	1.00	.94	.90	.89	.87	.77	.63
.81	.94	1.00	.95	.92	.89	.84	.77	.63
.72	.87	.94	.88	.86	.82	.77	.70	.63
.67	.76	.82	.77	.76	.73	.71	.63	.61
.62	.68	.75	.70	.67	.66	.67	.58	.56
.56	.61	.67	.62	.58	.59	.59	.52	.51

Projection of Horn
Horn
70 cm
Mappin
Plane
2.54 cm Square Grid

FIGURE 4-7

POWER DENSITY CONTOURS IN MEDIAN PLANE OF CAGE

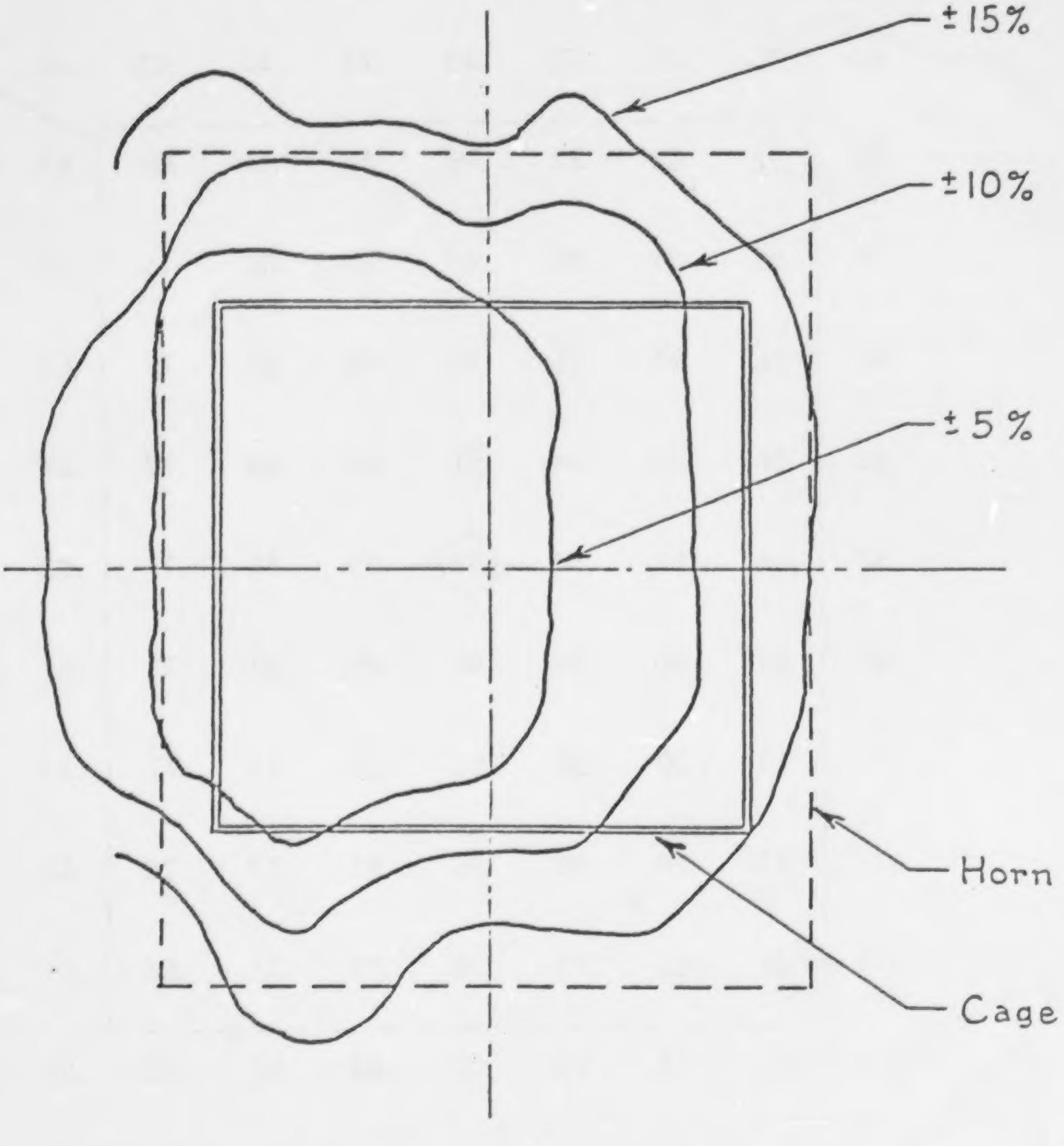

±15%
±10%
±5%
Horn
Cage

TABLE 4-13

SUMMARY OF MICROWAVE EXPERIMENTS ON SOCIAL INTERACTION

Acute Exposure (October '79 - April '80)

Species	No. of Flocks** Studied	Total Exposed / Total Birds	Exposure Power Density (mW/cm^2)	Duration (min.)
*WTSP	1	1/6	25	20
	2	2/12	25	200
+DEJU	2	3/12	0(Sham)	20
	3	3/18	25	20
	4	7/24	100	20
	2	4/12	155	7-10

* WTSP = White-throated Sparrow

+ DEJU = Dark-eyed Junco

** Each flock consisted of six birds

4.3.1.5 Behavioral Response During Irradiation

Before the start of the irradiation process, birds in the exposure cage were generally alert and active, hopping around in the cage. This activity continued throughout the exposure period with differences in intensity dependent on the power density and length of exposure. The non-treated flock-mates of each irradiated bird that were placed in holding cages were observed to have a similar pattern of activity (i.e. hopping around the holding cage with periodic rests). During 20 minute exposures at 25 mW/cm^2, the irradiated birds showed the same activity as non-irradiated flock-mates. Similarly, during the 200 minute exposure, the activity pattern was unchanged, except that the birds appeared to rest more frequently than the ones not irradiated.

At 100 mW/cm^2, exposed birds appeared to be less active than the others, and all held their beaks open for minutes at a time. Holding the beak open (gaping) is a mechanism which allows birds to increase rate of heat loss from their bodies during hot weather or at time of heat stress. Birds exposed to 155 mW/cm^2 gaped continuously during the seven to ten minutes of irradiation. Non-irradiated, or sham control, birds never showed this gaping behavior.

A second mechanism used by birds to conserve body heat in cold weather is plumage erection. This traps warm air under the feathers, and helps insulate the bird from the cold. Some of the microwave exposures were carried out at temperatures ranging between 0 and $7^{0}C$. At these low temperatures most birds not exposed to microwaves maintained fluffed feathers. Birds exposed to 25 or 100 mW/cm^2 on these cold days had a markedly less fluffed appearance during the period of their exposure, suggesting that the absorbed microwave energy reduced the thermogenic needs of the birds.

Our observations indicate that if the bird survives near lethal doses of irradiation, its activity level and behavior appear normal upon termination of the exposure and return to the aviary or observation cage (two of the birds exposed to microwave radiation of 155 mW/cm^2 died during exposure). We have observed no marked propensity for the irradiated bird to either lead or lag non-irradiated birds in the movement to food and water which seem to occur within five minutes after returning the birds to the cage after irradiation.

4.3.1.6 Social Behavior Response - Post Irradiation

Table 4-14 contains a completed dominance hierarchy matrix. Shown are responses before irradiation of the test bird which is marked with an asterick. The vertical order of birds in the left most column of each matrix is the dominance order of the group in descending order.

The exposure conditions and response to irradiation for each irradiated individual, along with the three sham controls, is shown in Table 4-14. Based on visual examination of the data in hierarchy matrices it appears that with one exception (at 155 mW/cm^2) no changes in dominance position have occurred in the social structure of the experimental flocks.

Although the irradiated birds maintained their positions in the hier-

TABLE 4-14

Effects of Microwaves on Bird Behavior (Hierarchy)

Cage #					Level of Aggressive Activity (per 15 min.)					
	Initial Hierarchy of Exposed Bird	Duration of Exposure (in min.)	T°C at Time of Exposure	Absolute Hierarchy Position	Bird Above the Exposed Bird in the Hierarchy Toward the Exposed Bird		Relative Hierarchy Position	Exposed Bird Toward the Bird Below It		Relative Hierarchy Position
$0 mW/cm^2$					Before	After		Before	After	
6	3	20	-7°	None	2.30 (39)[a]	1.48 (27)	↑	1.03 (39)	2.07 (27)	↑
3B	2	20	3°	None	1.19 (23)	0.70 (20)	↑	1.41 (23)	1.80 (20)	↑
3B	4	20	3°	None	0.97 (23)	0.50 (20)	↑	0.97 (23)	0.50 (20)	↓
$25 mW/cm^2$					Degree of Dominance					
2	3	20	-7°	None	1.43 (37)	0.91 (22)	↑	1.27 (37)	0.91 (22)	↓
3A	4	20	-6°	None	0.33 (43)	0.31 (45)	↑	1.12 (43)	1.57 (45)	↓
4	3	20	-3°	None	2.26 (37)	1.81 (37)	↑	1.21 (37)	1.43 (21)	↑
5[w]	3	20	-7°	None	2.72 (29)	1.12 (26)	↑	2.72 (29)	0.93 (26)	↓
7[w]	4	200	-7°	None	0.44 (34)	1.67 (15)	↓	0.62 (34)	2.33 (15)	↑
1[w]	3	200	2°	None	1.43 (35)	2.30 (20)	↓	0.94 (35)	2.00 (20)	↑
$100 mW/cm^2$										
2A	2	20	-3°	None	1.00 (31)	0.47 (30)	↑	1.29 (31)	1.04 (30)	↓
2A	4	20	-3°	None	1.00 (31)	1.79 (30)	↓	2.19 (31)	1.92 (30)	↓
4A	2	20	4	None	2.04 (23)	1.10 (21)	↑	1.30 (23)	1.62 (21)	↑
4A	4	20	4	None	1.26 (23)	1.62 (21)	↓	2.65 (23)	2.62 (21)	↓
5A	3	20	6	None	0.88 (26)	1.59 (29)	↓	0.69 (26)	0.86 (29)	↑
1A	2	20		None	1.41 (21)	0.73 (22)	↑	0.62 (21)	0.55 (22)	↓
1A	4	20		None	2.76 (21)	1.27 (22)	↑	1.29 (21)	2.14 (22)	↑
$155 mW/cm^2$										
7A	3	7		- - -	1.47 (32)	- - -		0.94 (32)	- - -	
7A	5	7		None	0.25 (32)	0.24 (33)	↑	0.81 (32)	0.67 (33)	↓
6A	2	10		Down	1.58 (24)	1.16 (31)	↑	0.92 (24)	-0.23	↓
6A	4	10		- - -	0.83 (24)	- - -		1.50 (24)		

---

[a] number of 15 minute periods used to calculate mean level of aggression

[w] White-throated Sparrow (all others, Dark-eyed Juncos)

archies, some appeared to have a change in their level of aggression after exposure. To analyze this further we ranked the dosage and time of exposure (see x-axis of Figure 4-8) and considered the association between increasing dosage and time of exposure and the percentage of birds that moved down in the hierarchy after exposure. When the exposed bird was compared to the bird immediately above it in the hierarchy we did not find a significant correlation (Spearman rank correlation, $r_s = 0.11$, $p>0.50$). When the exposed bird was compared to the bird immediately below it, the association between increasing the dosage and time of exposure versus the percentage of birds that moved down in the hierarchy after exposure was also not significant (Spearman rank correlation, $r_s = 0.81$, $p>0.05$).

4.3.2 Lethal Dose Experiment

4.3.2.1 Experimental Description

Because the determination of dose-response relationships are an essential part of the overall research program and because the early identification of stress-signaling behavior would improve the efficiency of the observations in all subsequent experiments, we have performed a series of high dose exposures using eight Dark-eyed Juncos.

Four of the eight birds were exposed as a part of the established social dominance experiment. These exposures were performed using the two cages side-by-side. Because one bird of each simultaneously-exposed pair died while no ill effects were apparent on the second bird, we had reason to suspect a possible non-uniformity in the radiation field. Although

Figure 4-8 Movement Within the Hierarchy of The Exposed Bird After Exposure

a. The Exposed Bird Compared to the Bird Above it in the Hierarchy

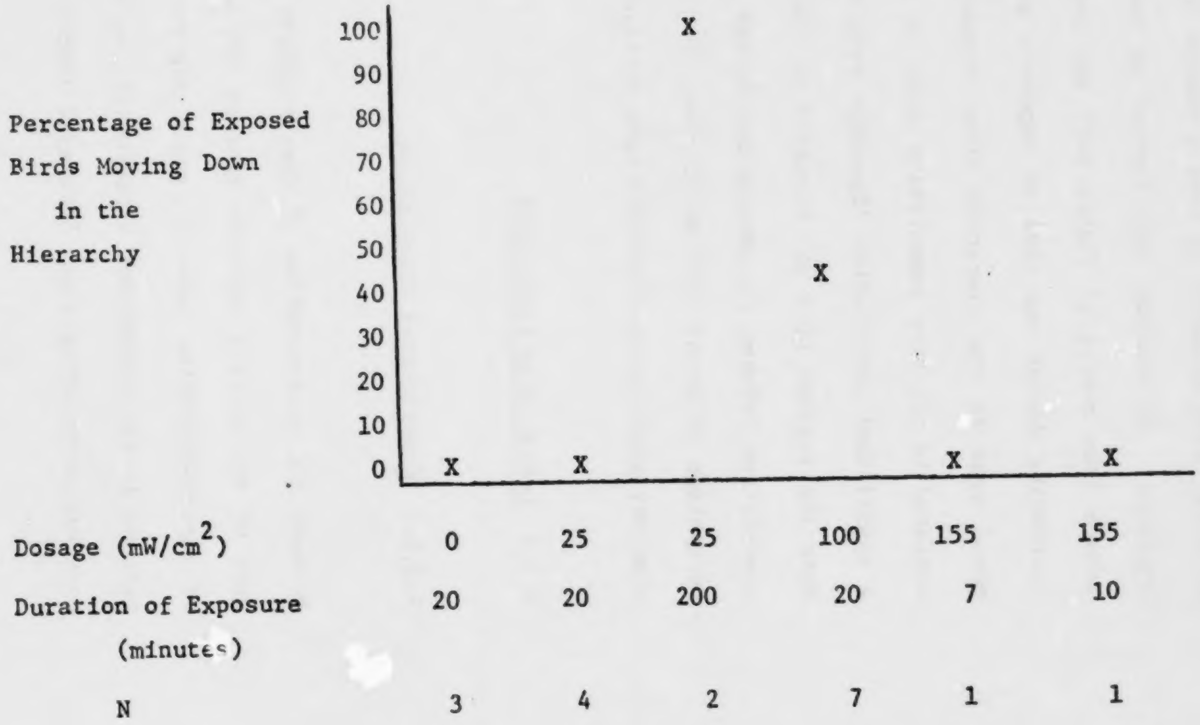
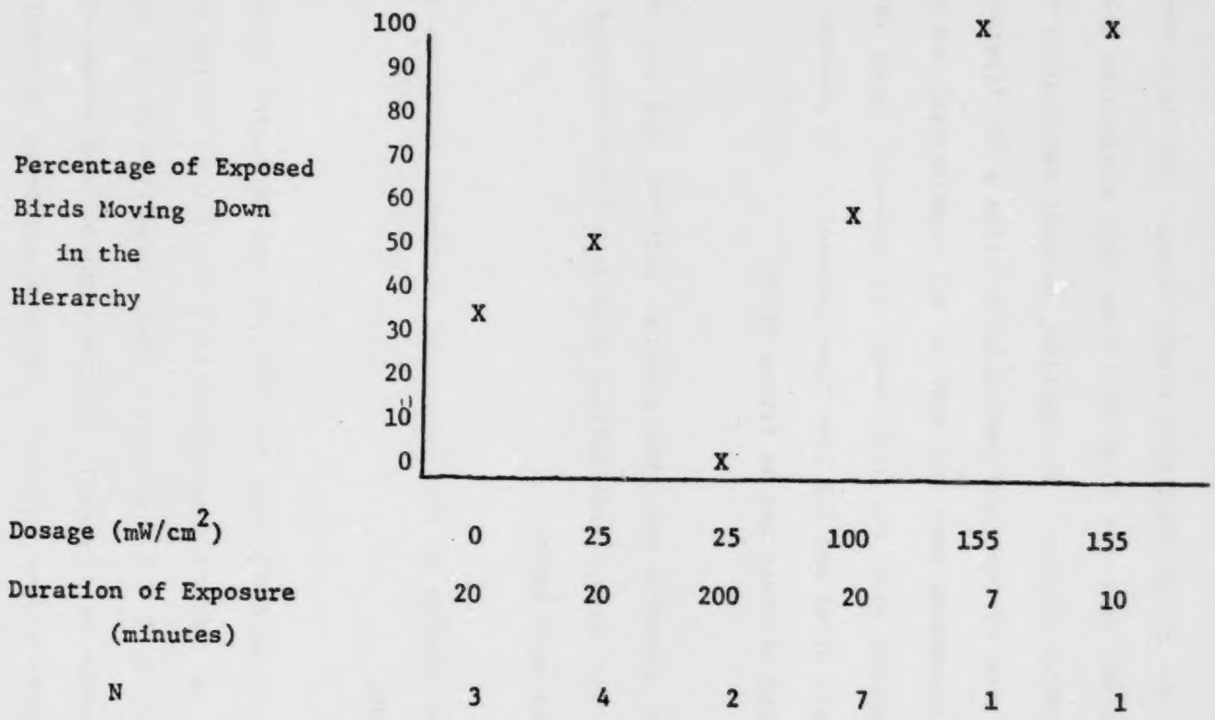


FIGURE 4-8 (CONTINUED)

b. The Exposed Bird Compared to the Bird Below it in the Hierarchy



measurement demonstrated that this was not the case, we elected to perform a short series of high-dose experiments using birds which were not a part of the social structure study flocks. For this series of experiments we exposed only one bird at a time thus minimizing the potential field uniformity problem. In addition, cloacal temperature measurements were made on some of the experimental birds using a YSI Telethermometer. Temperature measurements were not made on all experimental subjects because the probe supplied with the instrument was somewhat large for the cloaca of these small birds and its long time constant (> 30 seconds) compounded the difficulty of their use on living birds.

The exposure and observational protocol was the same as that described earlier except that neither sham-irradiated controls nor social interaction data [illegible] taken.

The results of this series of microwave exposures are presented in Table 4-15.

It is apparent that the LD50 for the Dark-eyed Junco exposed to microwaves at an ambient temperature of 7 to 13°C is on the order of 150-160 mW/cm^2 over 7.25 ± 0.5 minutes. Power densities of 100 to 130 mW/cm^2 appear to produce no externally visible signs of heat stress other than gaping over a twenty minute exposure. We have succeeded in identifying certain stress-related behaviors that were useful throughout the program. They are (a) gaping, (b) panting, (c) crouching and (d) loss of muscular coordination or of equilibrium. The rapid onset of gaping is especially interesting. It has been observed at all power levels from 25 mW/cm^2 to 160 mW/cm^2. Its

TABLE 4-15

LETHAL DOSE EXPERIMENTS - DARK-EYED JUNCOS

Number of Birds	Microwave Power Density (mW/cm^2)	Survival Rate	Time to Death	Cloacal Temperature	
				Before	After
4	150	50%	7:15 ± 15 sec.	-	-
2	160	0%	6:30 ± 20 sec.	36.9°C	42.3°C
2	130	100%	Survived	37.9°C	38.6°C

occurrence as soon as 30 seconds after the start of exposure is difficult to explain as a response to generalized body thermal loading. It has been suggested that highly localized heating of noncutaneous thermally sensitive sensors by penetrating microwaves may serve as thermoregulatory triggers of generalized response, under conditions in which neither skin nor core temperature changes, would suggest the initiation of thermoregulatory behavior.

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4.4 THERMOREGULATORY RESPONSE OF BIRDS TO MICROWAVE FIELDS

4.4.1 Thermoregulatory Behaviors of Birds Exposed to Microwave Radiation

4.4.1.1 Introduction

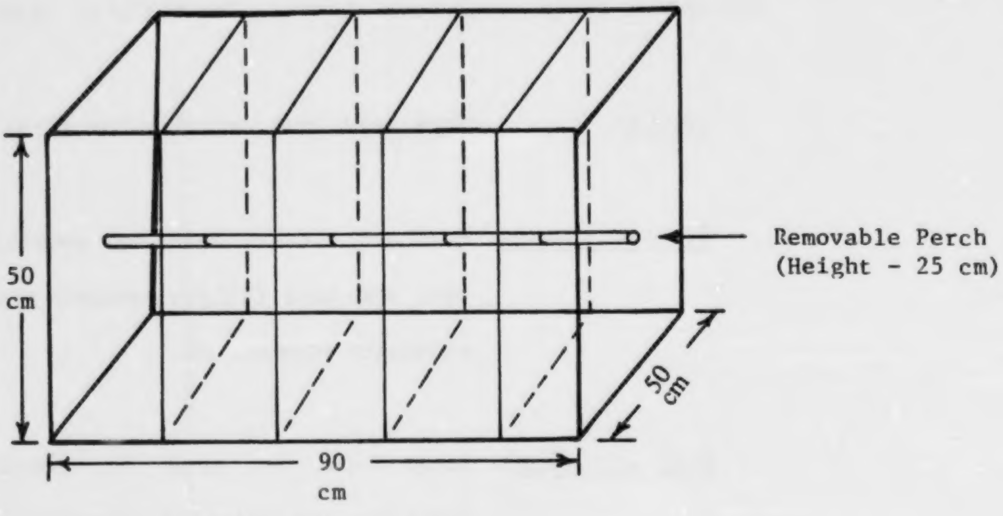
During preliminary aversion/attraction studies, microwave exposed birds exhibited specified patterns of thermoregulatory behavior in response to power densities of 25, 36 and 50 mW/cm^2. To investigate further the relationship between microwave exposure and the onset and duration of these behaviors, a series of additional experiments were carried out to study thermoregulatory behaviors of House Finches (small sized bird - 17 to 24 g) and Blue Jays (medium sized bird - 75 to 100 g) to microwave irradiation. Ten birds of each of the two species were exposed at each of five power densities: 0.1, 1, 10, 25, and 50 mW/cm^2.

4.4.1.2 General Procedure

Experiments were conducted in a cage whose dimensions were 0.9 m x 0.5 m x 0.5 m (Figure 4-9). This cage was subdivided into 5 smaller compartments so that five individual birds could be viewed or observed simultaneously. A rod was inserted in the center of each compartment to enable birds to perch. The same 10 individuals of each species were used throughout the entire series of thermoregulatory behavior experiments. Each 30-minute test period was divided into three periods of 10 minutes each; a pre-exposure, an exposure, and a post-exposure period. Body masses were measured before each experiment to obtain pre-treatment values and used as a measure of the general condition of the birds. Ambient temperature and relative humidity of the laboratory were measured and recorded for each

FIGURE 4-9

MICROWAVE TRANSPARENT CAGE USED TO MEASURE RESPONSES TO THERMOREGULATORY STRESS


Removable Perch
(Height - 25 cm)
50
cm
50
cm
90
cm

experiment. Using a scan sampling technique (Altmann, 1974) the thermoregulatory responses of each individual bird were classified and recorded every 20 seconds during the 30-minute test period.

In these experiments, each of the five birds in the cage was observed once every 20 seconds. For microwave exposures, the cage was placed in the exposure chamber with the perch oriented parallel to the E vector of the microwave field. Thus, birds sitting on the perch were oriented perpendicular to the E vector of the microwave field.

To quantify thermoregulatory behavior, birds were observed for one or more of the four distinctive postures which represent behavioral responses to increasing thermoregulatory stress. The postures studied were:

Gaping: Beak held open, usually the first sign of stress.

Sleeked plumage: Feathers sleeked down and smooth, neck stretched out, and legs fully extended, giving the body an elongated appearance.

Wing spreading: Wings held out from the sides of the body, sometimes periodically retracted and extended.

Panting: Very rapid breathing as indicated by rhythmic movements of the bird's throat and/or body.

Since several of these postures can occur simultaneously, the intensity of a bird's thermoregulatory response was assessed by using the following system of scoring:

Level 0	no observable response
Level 1	slight gaping
Level 2	full gape, sleeked plumage, discontinuous wing spreading
Level 3	full gape, sleeked plumage, moderate wing spreading, slight panting
Level 4	full gape, sleeked plumage, full wing spreading, full panting

With this scoring method, we were then able to relate the behavioral response of birds to microwave exposure and provide data on the following:

- Power density at which birds first exhibited signs of thermoregulatory behavior after the onset of microwave irradiation;

- Average time elapsed between onset of exposure and appearance of thermoregulatory responses;

- Average recovery time, i.e., time between the end of the exposure and disappearance of the thermoregulatory behavior;

- Intensity of each of the responses to different levels of microwave irradiation.

4.4.1.3 Results and Discussion

Studies of thermoregulatory behavior in House Finches were conducted between 11 August and 15 August 1980; those for Blue Jays were conducted between 5 November and 14 November 1980.

With ambient temperatures ranging from 22.2°C to 28.3°C ($\bar{X}$ = 24°C, S.D.= 1.9) and relative humidities ranging from 67% to 79% ($\bar{X}$ = 71%, S.D. = 4), House Finches exhibited no signs of thermoregulatory stress during or after exposure to microwaves at power densities of 0.1, 1, and 10 mW/cm^2 (Table 4-16). Only a slight intermittent gaping was observed in two birds after 8.3 minutes following the onset of microwave irradiation at 25 mW/cm^2 (Table 4-17). This response disappeared before the termination of the exposure period.

During exposure to 50 mW/cm^2, most House Finches began to gape after approximately 100 seconds of irradiation, and continued gaping throughout the exposure period (Table 4-18). Some individuals continued to gape for 160 seconds after termination of the irradiation. Sleeked plumage, wing spreading, and panting in House Finches were observed only at 50 mW/cm^2

TABLE 4-16. THERMOREGULATORY RESPONSE OF HOUSE FINCHES EXPOSED TO MICROWAVE IRRADIATION

	Proportion of Time Birds Exhibited Thermoregulatory Behavior (%)														
Power Density	0.1 mW/cm^2			1 mW/cm^2			10 mW/cm^2			25 mW/cm^2			50 mW/cm^2		
Behavior	Pre	Exp	Post	Pre	Exp	Post	Pre	Exp	Post	Pre	Exp	Post	Pre	Exp	Post
Gaping	0	0	0	0	0	0	0	0	0	0	2.1	0	0	84.0	24.7
Sleeked Plumage	0	0	0	0	0	0	0	0	0	0	0	0	0	71.7	14.7
Wings Spread	0	0	0	0	0	0	0	0	0	0	0	0	0	71.7	14.7
Panting	0	0	0	0	0	0	0	0	0	0	0	0	0	49.0	5.3
Ambient Temp (°C)		24.4			22.2 (5 birds) 28.3 (5 birds)			23.8 (5 birds) 25.5 (5 birds)			23.3			23.3 (5 birds) 23.6 (5 birds)	
Relative Humidity (%)		79.0			70.5			70.0			67.5			70.5	

n = 10
Pre = pre-exposure
Exp = exposure
Post = post-exposure (10 minutes)

TABLE 4-17

Thermoregulatory Response of House Finches and Blue Jays Exposed to Microwave Irradiation of 25 mW/cm^2

	Latency and Persistence of Thermoregulatory Responses	
	Mean Latency[a] (min. ± S.D.)	Mean Persistence[b] (min. ± S.D.)
A House Finches (n = 10, $\bar{X}$ mass = 20.7 g)		
Gaping	8.3 ± 2.3 (2)	0 (2)
Sleeked Plumage	N.R.	N.R.
Wings Spread	N.R.	N.R.
Panting	N.R.	N.R.
B Blue Jays (n = 10, $\bar{X}$ mass = 85.1 g)		
Gaping	4.6 ± 2.9 (9)	0.2 ± 0.3 (9)
Sleeked Plumage	4.9 ± 2.9 (7)	0 (7)
Wings Spread	4.9 ± 2.9 (7)	0 (7)
Panting	N.R.	N.R.

---

[a] Latency is the time interval between the beginning of the microwave exposure and the appearance of the response. Mean time is based only on the number of birds responding during the ten minute exposure.

[b] Persistence is the interval between the ending of the microwave exposure and the disappearance of the response. Mean time is based on the number of birds responding during the ten minute exposure. Those individuals which ceased responding immediately upon removal of the microwave field are included in the mean as zero cessation time.

( ) = the number of birds that exhibited the response.

N.R. = response not observed.

TABLE 4-18

Thermoregulatory Response of House Finches and Blue Jays Exposed to Microwave Irradiation of 50 mW/cm^2

	Latency and Persistence of Thermoregulatory Responses	
	Mean Latency[a] (min. S.D.)	Mean Persistence[b] (min. S.D.)
A House Finches		
(n = 10, $\bar{X}$ mass = 20.7 g)		
Gaping	1.7 ± 0.9 (10)	1.5 ± 0.9 (10)
Sleeked Plumage	2.5 ± 1.0 (10)	2.3 ± 1.3 (10)
Wings Spread	2.5 ± 1.0 (10)	2.3 ± 1.3 (10)
Panting	2.7 ± 1.3 (8)	4.5 ± 1.2 (9)
B Blue Jays		
(n = 10, $\bar{X}$ mass = 85.1 g)		
Gaping	2.7 ± 2.2 (10)	3.9 ± 1.0 (10)
Sleeked Plumage	1.6 ± 2.2 (10)	2.7 ± 1.0 (10)
Wings Spread	1.6 ± 2.2 (10)	2.7 ± 1.0 (10)
Panting	0.8 ± 1.2 (8)	2.1 ± 0.4 (9)

---

[a] Latency is the time interval between the beginning of the microwave exposure and the appearance of the response. Mean time is based only on the number of birds responding during the ten minute exposure.

[b] Persistence is the interval between the ending of the microwave exposure and the disappearance of the response. Mean time is based on the number of birds responding during the ten minute exposure. Those individuals which ceased responding immediately upon removal of the microwave field are included in the mean as zero cessation time.

( ) = the number of birds that exhibited the response.

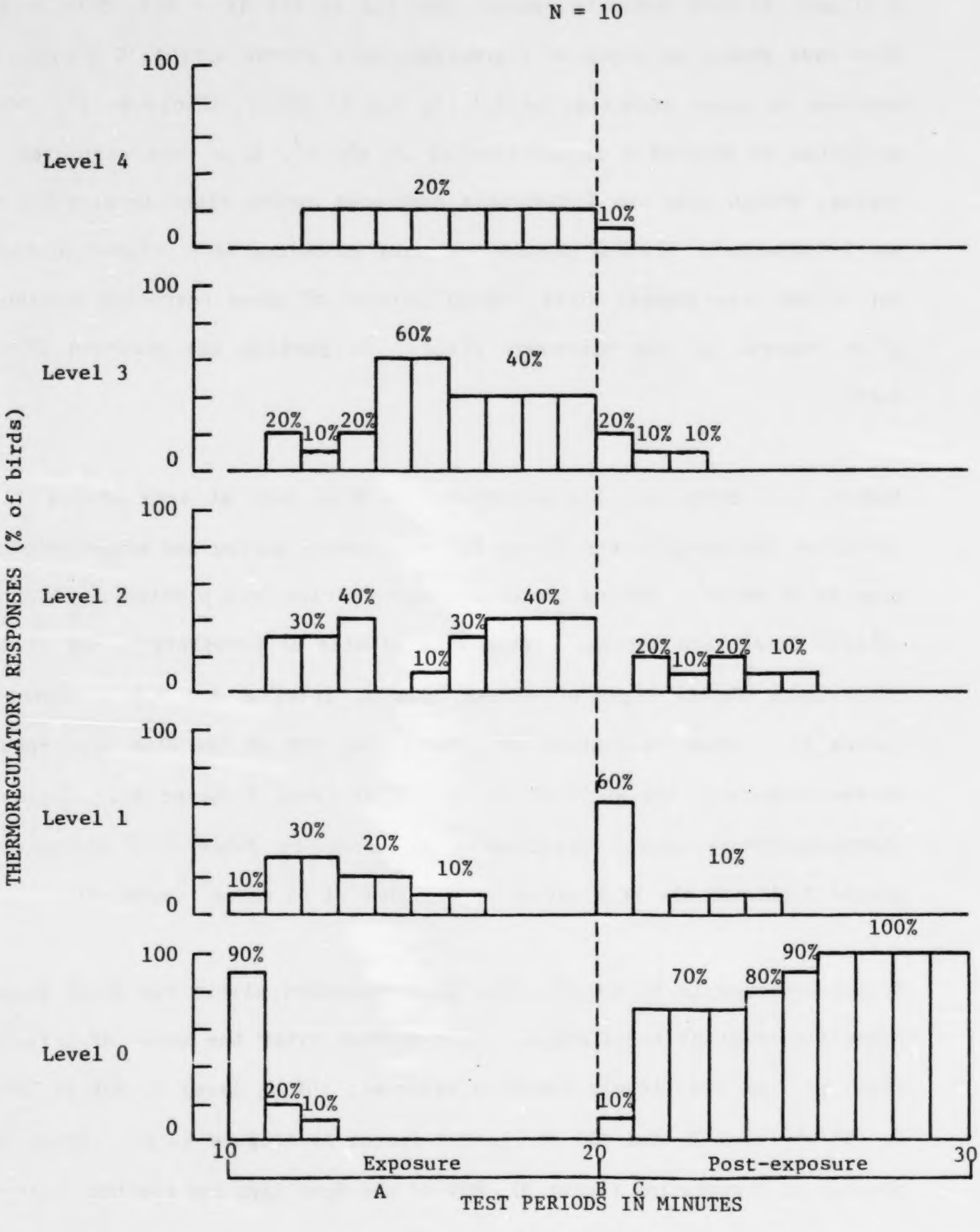
level. These responses continued for the duration of the exposure period. Seven of ten birds continued to respond with sleeked plumage and spread wings during the post-exposure period. Three of eight Houses Finches continued panting after the exposure was terminated (Table 4-18).

Figure 4-10 shows the percentage of birds at each of the five graded thermoregulatory levels (0-4) for each minute during and after exposure to 50 mW/cm^2. During the first ten minutes all birds were at a level of zero (no response) and not plotted. After five minutes of irradiation (point A), 60% of the House Finches were at level 3, 20% at level 4, and 20% at level 1. At the end of the ten-minute exposure (point B), 20% of the birds showed behavior of level 4, 40% at level 3 and 40% at level 2. After termination of irradiation, 70% of the House Finches returned to level zero within two minutes (point C). In the remaining 30%, thermoregulatory responses took somewhat longer to disappear.

The results of these experiments indicate that with mean ambient temperature of 24.0°C, and a mean relative humidity of 71%, House Finches exhibit no observable thermoregulatory behavior due to microwave exposure at power densities of less than 25 mW/cm^2. At 25 mW/cm^2, two of ten House Finches show low level thermoregulatory responses. At 50 mW/cm^2, all of the House Finches begin to show thermoregulatory behavior within two minutes following the onset of exposure. At 50 mW/cm^2 birds continue to respond for about 2.7 minutes following the termination of exposure. This indicates that House Finches recover rapidly even following exposure to 50 mW/cm^2 for ten minutes.

FIGURE 4-10

Percentage of House Finches (10) showing stress at each of the five thermoregulatory response levels during and after irradiation with 50 mW/cm^2.



(A = five minutes after onset of irradiation; B = ten minutes after onset of irradiation; C = one minute after termination of irradiation.)

During the studies of thermoregulatory behavior in Blue Jays, ambient temperature in the laboratory ranged from 20.0°C to 21.7°C ($\bar{X}$ = 20.6°C, S.D. = 0.5) and relative humidity ranged from 36% to 66% ($\bar{X}$ = 43%, S.D. = 9). Blue Jays showed no signs of thermoregulatory stress during 10 minutes of exposure to power densities of 0.1, 1, and 10 mW/cm^2 (Table 4-19). When subjected to microwave irradiation at 25 mW/cm^2, Blue Jays responded by gaping, though only two individuals continued gaping after termination of the irradiation. Sleeked plumage and wing spreading were evident in seven out of ten experimental birds, though neither of those responses continued after removal of the microwave field. No panting was observed (Table 4-17).

Figure 4-11 summarizes the percentage of Blue Jays at each of the five levels of thermoregulatory stress for each minute during and after irradiation at 25 mW/cm^2. During the pre-exposure period (not plotted), all birds exhibit level zero stress. After five minutes of irradiation, 40% of the individuals showed signs of stress, 30% at level 2 and 10% at level 1 (point A). After 10 minutes of irradiation, 50% of the Blue Jays showed stress responses, 30% at level 2, and 20% at level 1 (point B). Signs of thermoregulatory stress disappeared as shown in Table 4-17 within one minute following the termination of exposure at 25 mW/cm^2 (point C).

During exposure to 50 mW/cm^2, Blue Jays responded within the first minute after the onset of irradiation. Five minutes after the onset of irradiation, all ten individuals showed a response; 10% at level 1, 40% at level 2, 40% at level 3, and 10% at level 4 (point A) (Figure 4-12). After ten minutes of irradiation (point B), 80% of the Blue Jays had reached a stress

TABLE 4-19

Thermoregulatory Response* of Blue Jays Exposed to Microwave Irradiation

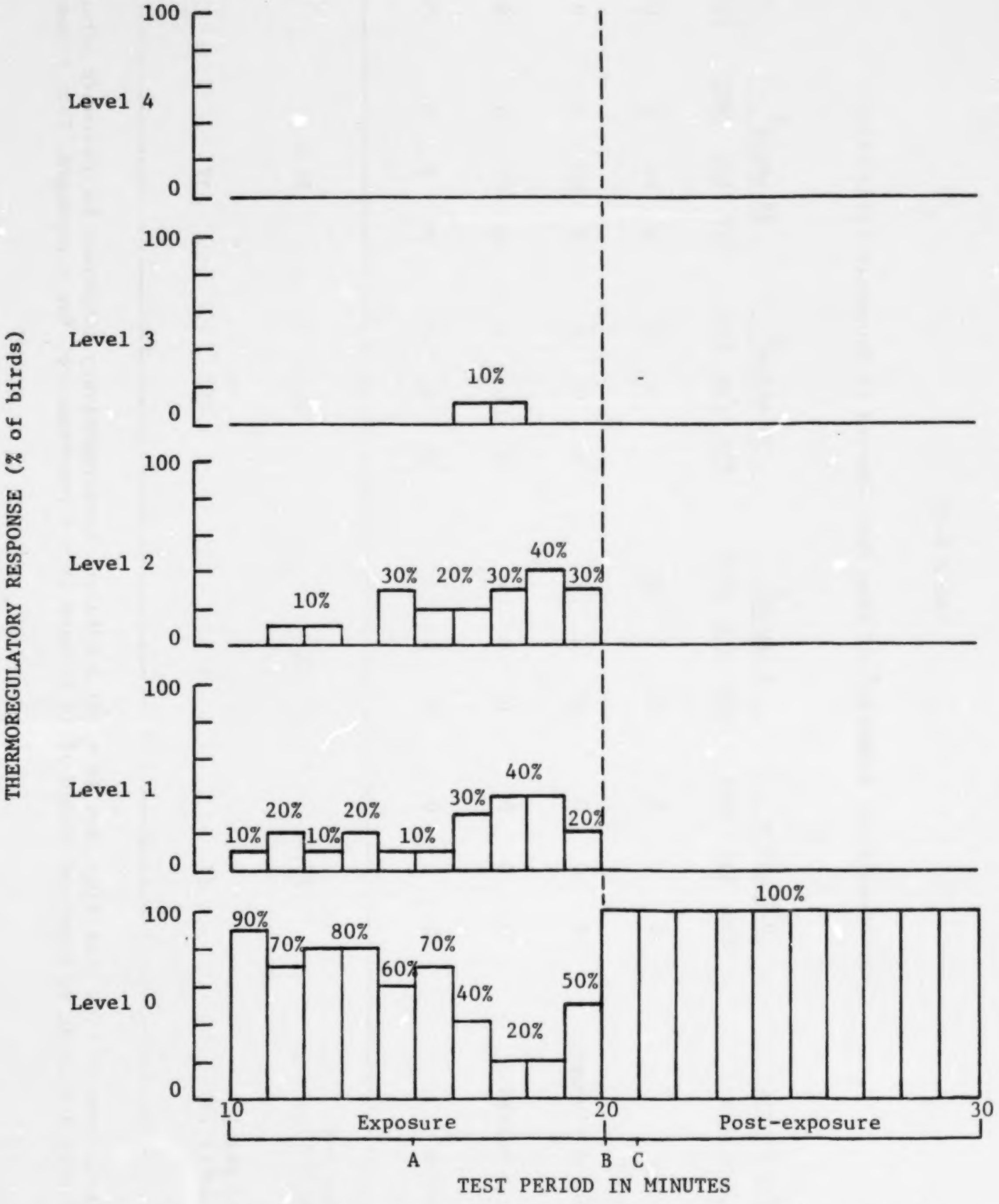
Power Density:	0.1 mW/cm^2			1 mW/cm^2			10 mW/cm^2			25 mW/cm^2			50 mW/cm^2		
Behavior	Pre	Exp	Post	Pre	Exp	Post	Pre	Exp	Post	Pre	Exp	Post	Pre	Exp	Post
Gaping	0	0	0	0	0	0	0	0	0	0	41	1	0	85	0
Sleeked Plumage	0	0	0	0	0	0	0	0	0	0	23	1	0	71	26
Wings Spread	0	0	0	0	0	0	0	0	0	0	23	1	0	71	26
Panting	0	0	0	0	0	0	0	0	0	0	0	0	0	17	7
$\bar{X}$ Ambient Temp (°C)		20.2			20.6			20.3			21.4			20.8	
$\bar{X}$ Relative Humidity (%)		57			47			37			37			38	

* Percentage of time that Blue Jays (n = 10) exhibited thermoregulatory responses to microwave irradiation during and after an exposure period of 10 minutes (Pre = pre-exposure, Exp = exposure, Post = post-exposure).

FIGURE 4-11

Percentage of Blue Jays showing stress at each of the five thermoregulatory response levels during and after irradiation with 25 mW/cm^2.

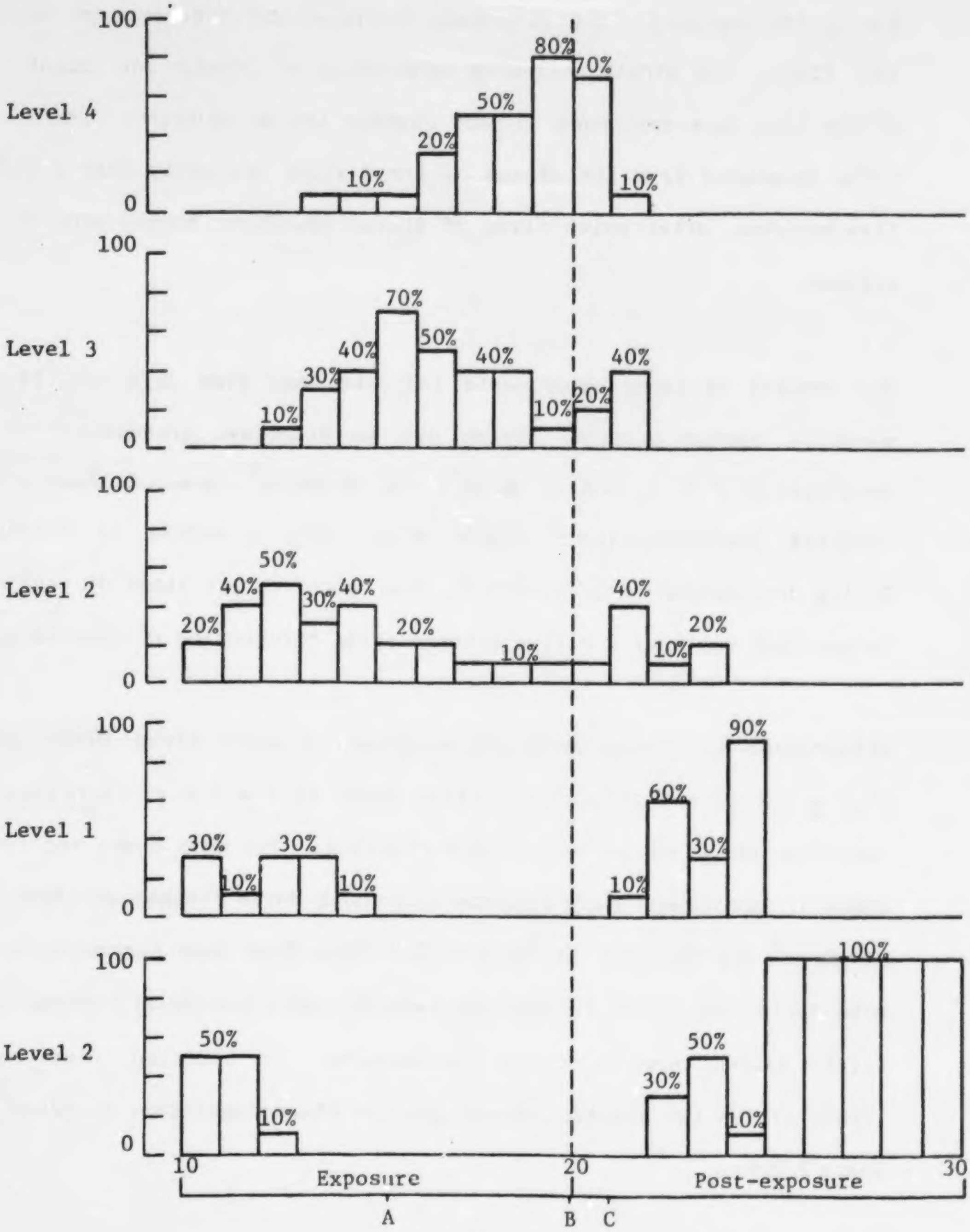
N = 10



(A = five minutes after onset of irradiation; B = ten minutes after onset of irradation; C = one minute after termination of irradiation.)

Percentage of Blue Jays showing stress at each of the five thermoregulatory response levels during and after irradiation with 50 mW/cm^2.

N = 10



(A = five minutes after onset of irradiation; B = ten minutes after onset of irradiation; C = one minute after termination of irradiation.)

level of 4, showing gaping, sleeked plumage, continuous wing spreading, and full, heavy panting. Nine out of the ten individuals exhibited panting during the exposure. All responses continued after removal of the microwave field. One minute following termination of irradiation (point C), 70% of the Blue Jays continued to show maximum thermoregulatory stress. These birds recovered from the stress of irradiation gradually over a period of five minutes, after which signs of thermoregulatory stress were no longer evident.

The results of these experiments indicate that Blue Jays exhibit no observable thermoregulatory stress due to microwave irradiation at power densities of 0.1, 1, and 10 mW/cm^2. At 25 mW/cm^2, however, Blue Jays show moderate thermoregulatory stress after only a minute of irradiation. During irradiation with 50 mW/cm^2, Blue Jays exhibit signs of considerable stress that continue for five minutes after termination of irradiation.

Differences in thermoregulatory response of small birds (House Finches) 20.7 ± 0.5 g) and large birds (Blue Jays) 85.1 ± 6.0 g) to microwave irradiation of 25 and 50 mW/cm^2 were observed. The mean onset and cessation times of thermoregulatory responses for both House Finches and Blue Jays at 25 mW/cm^2 are included in Table 4-17. Nine Blue Jays responded by gaping both during and after irradiation, whereas only two House Finches showed a slight gaping response during irradiation. In addition, Blue Jays, the larger of the two species, showed greater thermoregulatory behavior than do House Finches.

The mean onset and cessation times of thermoregulatory behavior of House

Finches and Blue Jays in response to 50 mW/cm^2 irradiation are summarized in Table 4-18. The incidence and onset of gaping, sleeked plumage, and wing spreading were similar for both species, although the mean onset time for panting was shortest in Blue Jays than for House Finches, suggesting that birds with the greatest mass are more sensitive to microwave imposed thermoregulatory stress. The mean time for cessation of panting in Blue Jays was nearly three times greater than for House Finches. The mean time for Blue Jays to recovery completely from microwave induced stress was one and a half times greater than for House Finches (Table 4-18) which suggests that larger birds recover more slowly from microwave induced thermoregulatory stress.

These results indicate that exposure to microwave power densities less than or equal to 50 mW/cm^2 does not represent a significant hazard to House Finches. However, continued exposure to 50 mW/cm^2 might tax the thermoregulatory capacities of these small birds. The extent of thermoregulatory stress observed in Blue Jays exposed to 50 mW/cm^2 suggests that prolonged exposure to microwaves under similar conditions would be severely debilitating. No residual effects on overall appearance of the bird or its behavior were observed in either House Finches or Blue Jays in two months following the microwave exposures.

4.4.2 Body Temperature of Birds During Microwave Irradiation

4.4.2.1 Introduction

Earlier experiments of behavioral responses of House Finches and Blue Jays to microwave irradiation indicated that House Finches begin exhibiting thermal stress behaviors at approximately 50 mW/cm^2, whereas Blue Jays begin exhibiting these behaviors at 25 mW/cm^2. An additional experiment was conducted to determine the correlation between changes in body temperature and corresponding changes in bird behavior during microwave irradiation.

4.4.2.2 General Procedure

Cloacal temperature was used as a measure of body temperature of House Finches and Blue Jays. Birds were monitored continuously before, during, and after ten minutes of exposure to selected microwave power densities. The ten minute exposure period was selected since this period corresponds to exposures used previously in the thermoregulatory behavior studies. Birds were restrained by enclosing them in plastic open mesh netting. In the restrained position birds were able to gape and pant, however, they were not capable of spreading their wings. They were then placed in a supine position on a styrofoam platform beneath the microwave irradiator. Cloacal temperatures were measured with a Narda microwave transparent probe inserted into the cloaca to a depth of one centimeter in House Finches, and a depth of 1.5 cm in Blue Jays. The lead from the probe was secured to both the netting and the styrofoam platform to prevent it from slipping out of the bird. The temperature signals from the Narda Temperature Monitor were recorded on a Hewlett Packard Digital Recorder. Measurements were taken every ten seconds during the three minutes prior to irradiation to establish the bird's pre-exposure temperature, every 10 s during the 10 minutes of microwave exposure, and finally at 10 s intervals during the five minutes following the (post)-exposure period. The temperature of the exposure chamber was also monitored.

Cloacal temperatures of House Finches exposed to 25 and 50 mW/cm^2 were recorded initially when the longitudinal axis of the bird was oriented perpendicular to the E vector of the microwave field, and then when the bird was oriented parallel to the E field. Temperatures of Blue Jays exposed to power densities of 10, 25, and 50 mW/cm^2 were recorded with the body oriented perpendicular to the E vector. Temperatures of Blue Jays exposed to 25 mW/cm^2 with the body oriented parallel to the E vector of the microwave field were also recorded. Sham irradiated (0 mW/cm^2) House Finches and Blue Jays were monitored to determine cloacal temperature fluctuations over a period of eighteen minutes and to assess the effects of handling and restraint.

Mean cloacal temperatures were obtained in each experiment for each minute of the pre-exposure, exposure, and post-exposure periods and the data were plotted in curves (Figures 4-13 to 4-23). The rate of increase in cloacal temperature during irradiation and the rate of decrease following termination of irradiation were calculated by the method of least squares regression analysis. The cloacal temperature immediately prior to irradiation (T_3 minutes), at the end of the ten minute exposure period (T_{13} minutes), the chamber temperature, the ambient temperature, and the relative humidity are presented in Table 4-20. Data for individual birds are presented in Appendices A4.4-1 to A4.4-11. Each bird was weighed prior to experimentation to monitor general condition. Ten individuals were used for each test unless otherwise noted.

FIGURE 4-13

Mean Cloacal Temperature for Nine Sham Treated House Finches Monitored for Eighteen Minutes

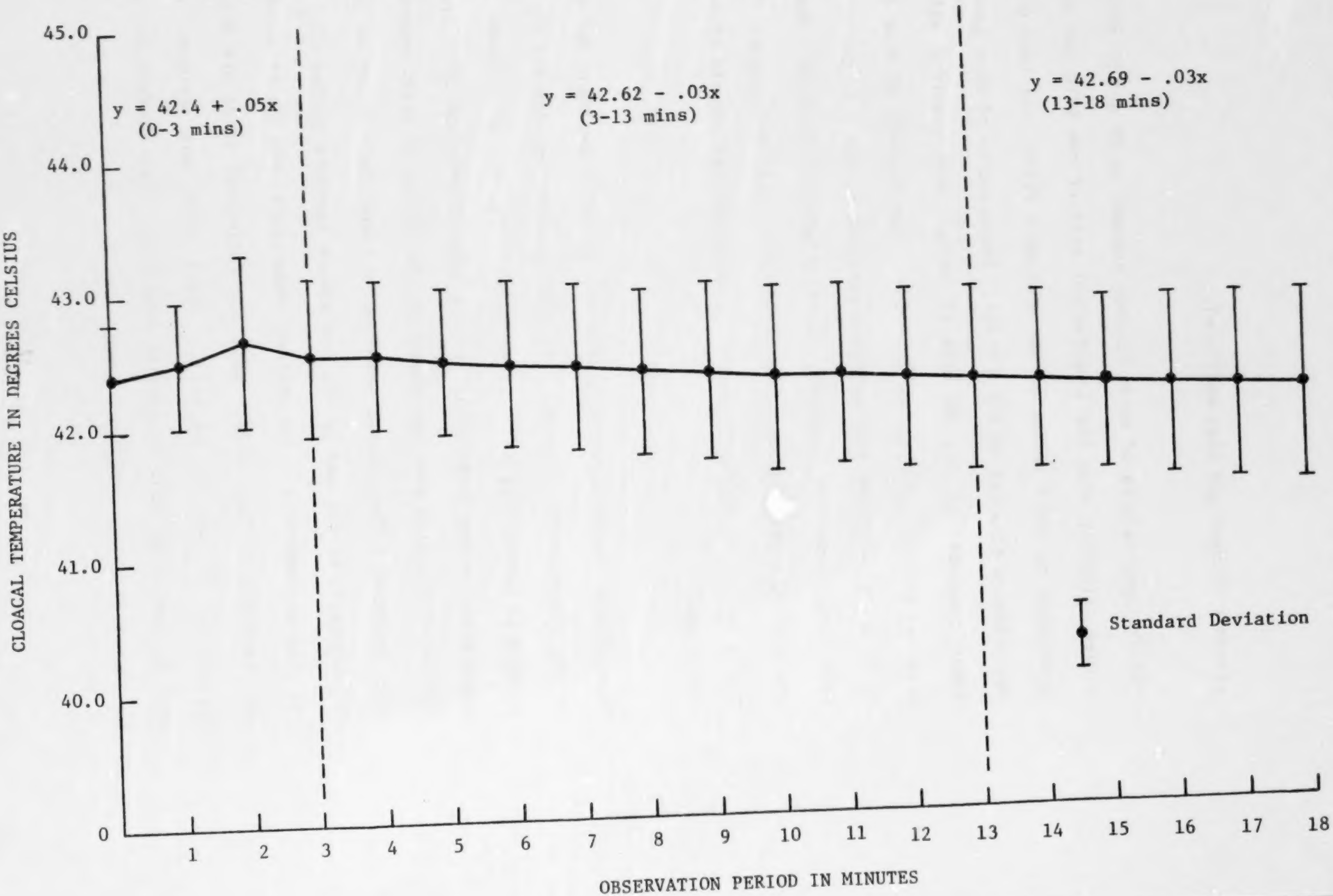


FIGURE 4-14

Mean Cloacal Temperature for Ten House Finches Irradiated with 25 mW/cm^2 Oriented Perpendicular to the E Vector of the Field. Exposure period begins at minute three and ends at minute thirteen.

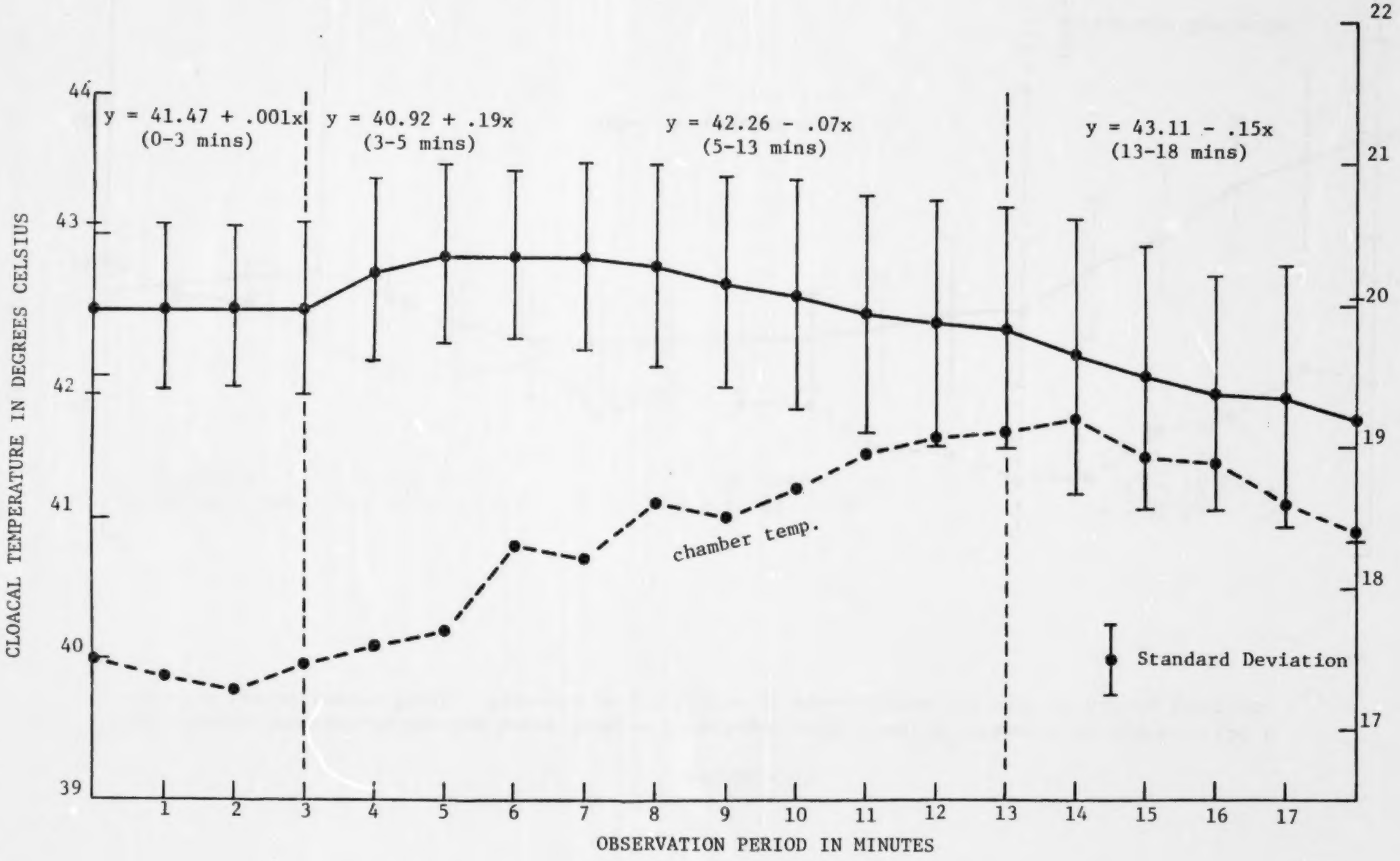


FIGURE 4-15

Mean Cloacal Temperature for Ten House Finches Irradiated with 25 mW/cm^2 Oriented Parallel to the E Vector of the Microwave Field. Exposure period begins at minute three and ends at minute thirteen.

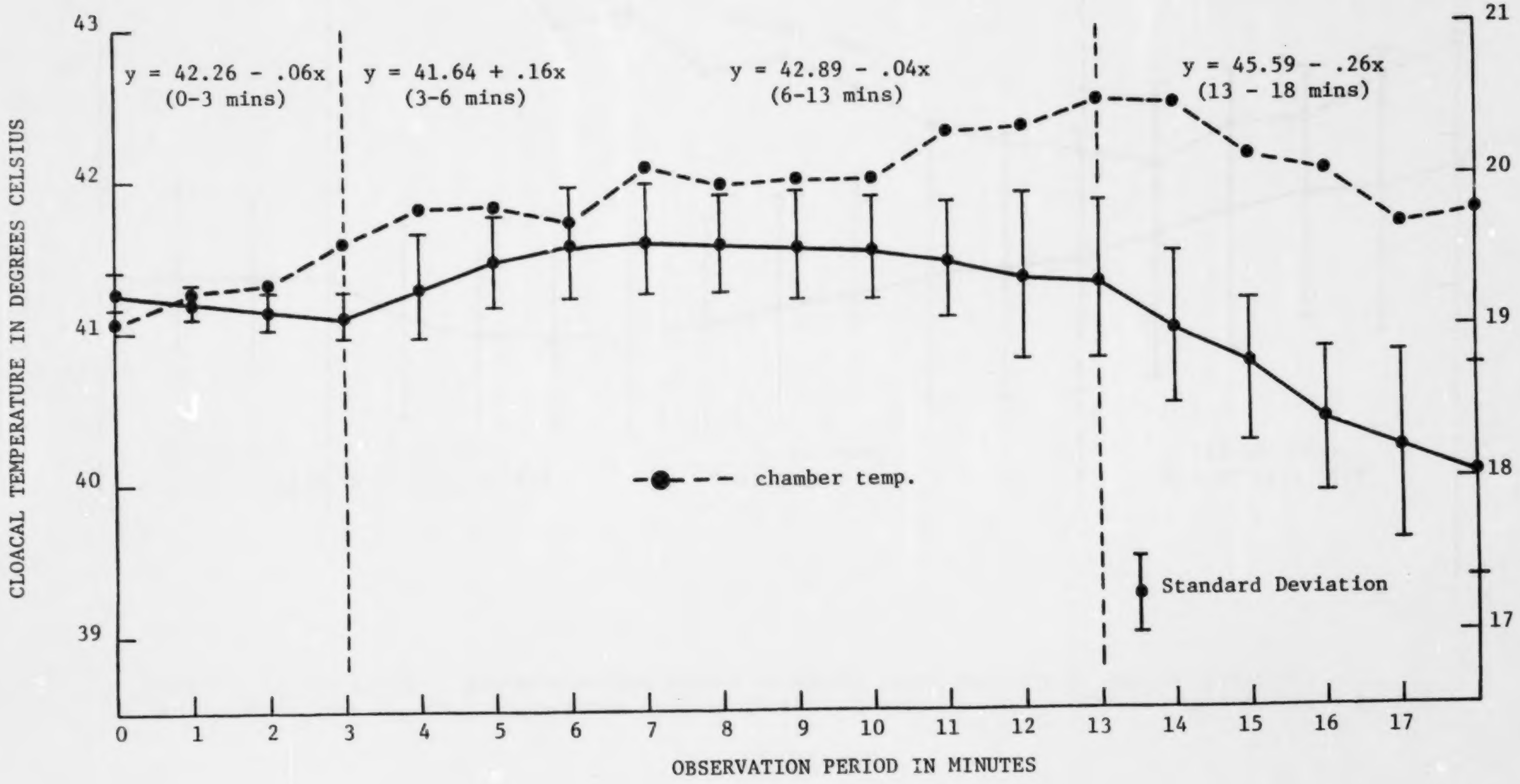
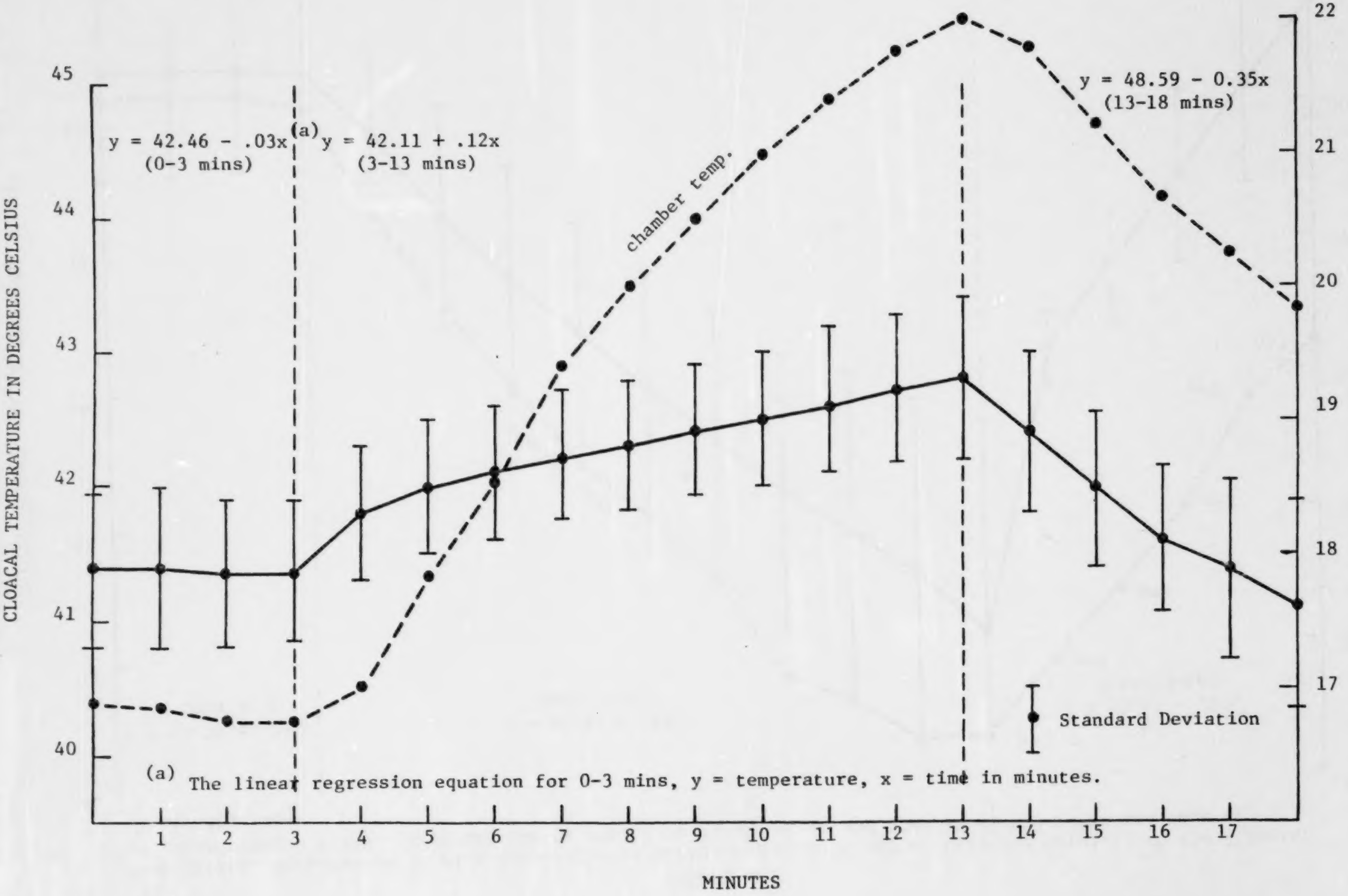


FIGURE 4-16

Mean Cloacal Temperature for Ten House Finches Irradiated at 50 mW/cm^2 Oriented Perpendicular to the E Vector of the Microwave Field. Exposure period begins at minute three and ends at minute thirteen.



(a) The linear regression equation for 0-3 mins, y = temperature, x = time in minutes.

FIGURE 4-17

Mean Cloacal Temperature of Five House Finches Irradiated with 50 mW/cm^2 Oriented Parallel to the E Vector of the Microwave Field. Exposure period begins at minute three and ends at minute three and ends at minute thirteen.

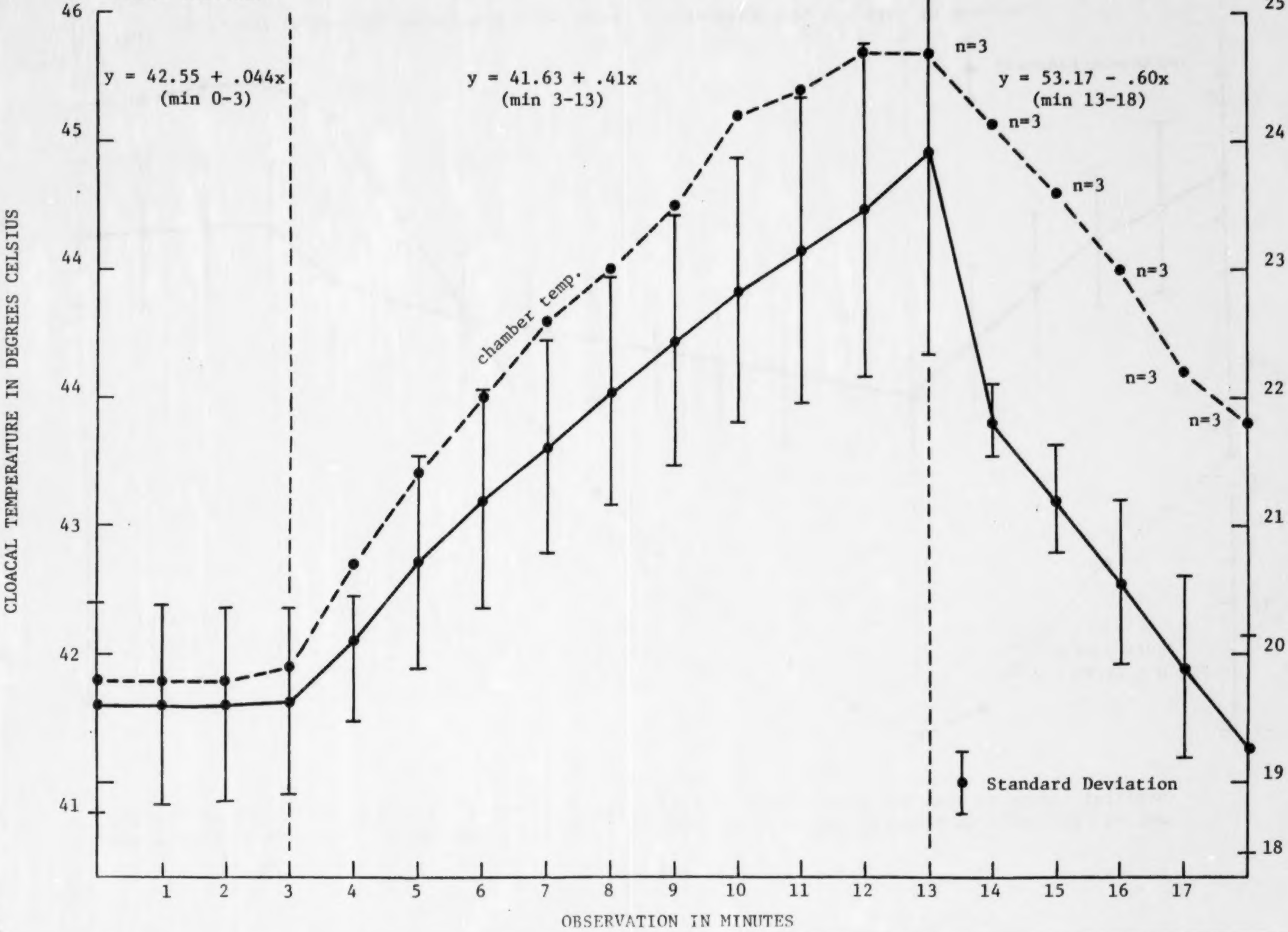


FIGURE 4-18

Mean Cloacal Temperature and Mean Chamber Temperature for House Finches Irradiated Perpendicular and Parallel to the 50 mW/cm^2 Microwave Field. (Dotted lines represent chamber temperature; solid lines represent cloacal temperature.)

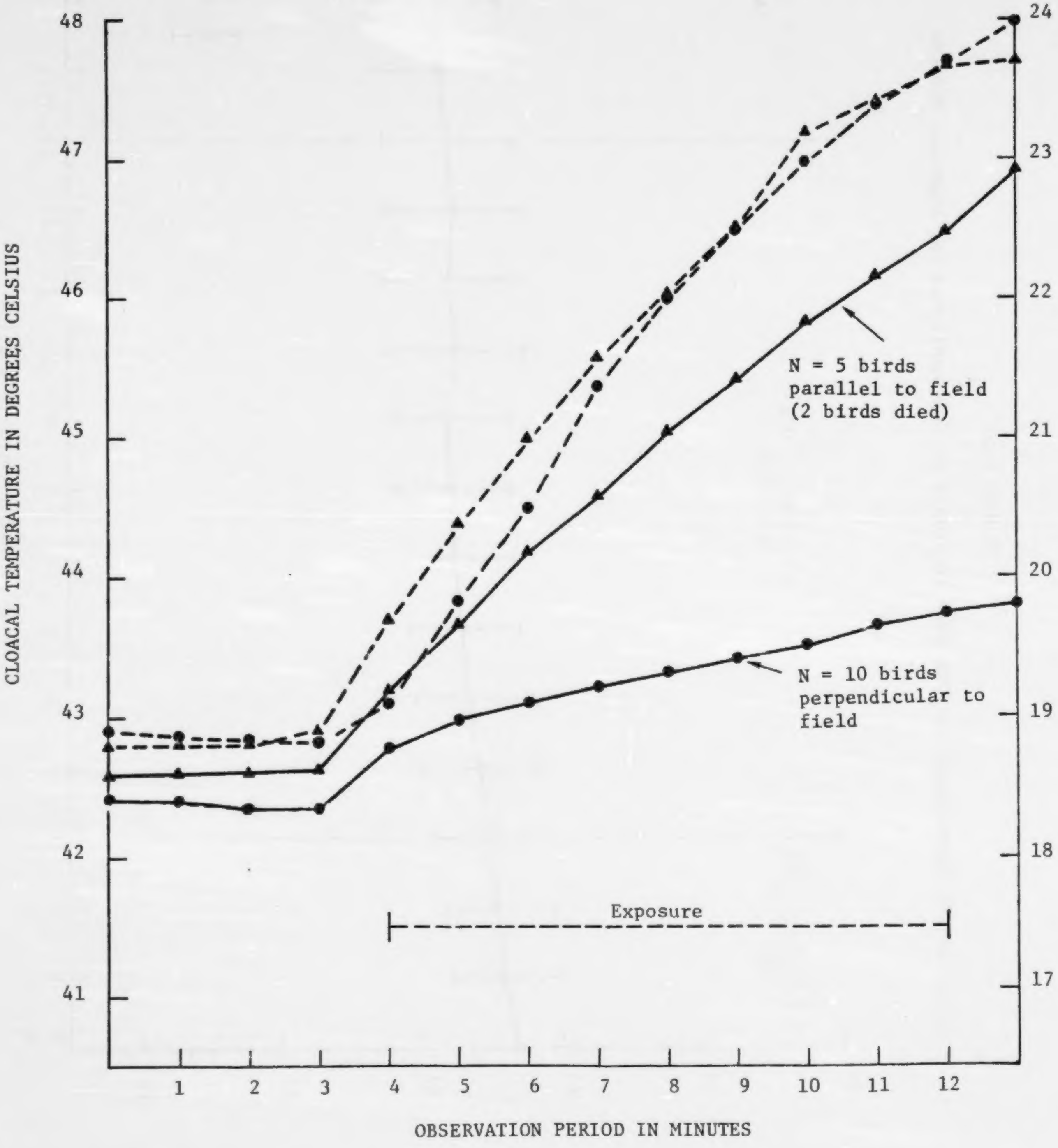


FIGURE 4-19

Mean Cloacal Temperature for Ten Sham Treated Blue Jays Monitored for Eighteen Minutes

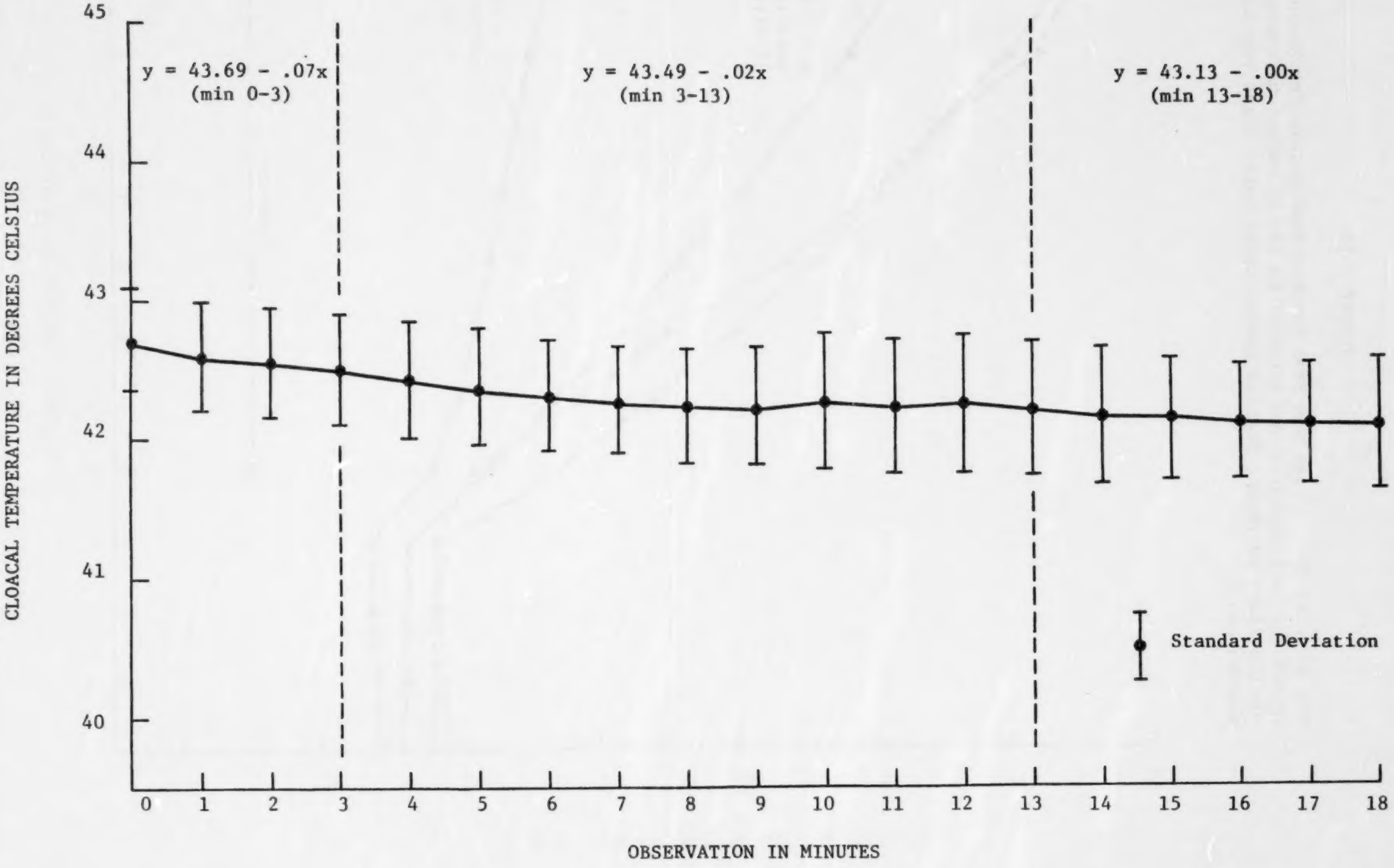


FIGURE 4-20

Mean Cloacal Temperature for Ten Blue Jays Irradiated with 10 mW/cm^2 Oriented to the E Vector of the Microwave Field. Exposure period begins at minute three and ends at minute thirteen.
---- represents chamber temperature

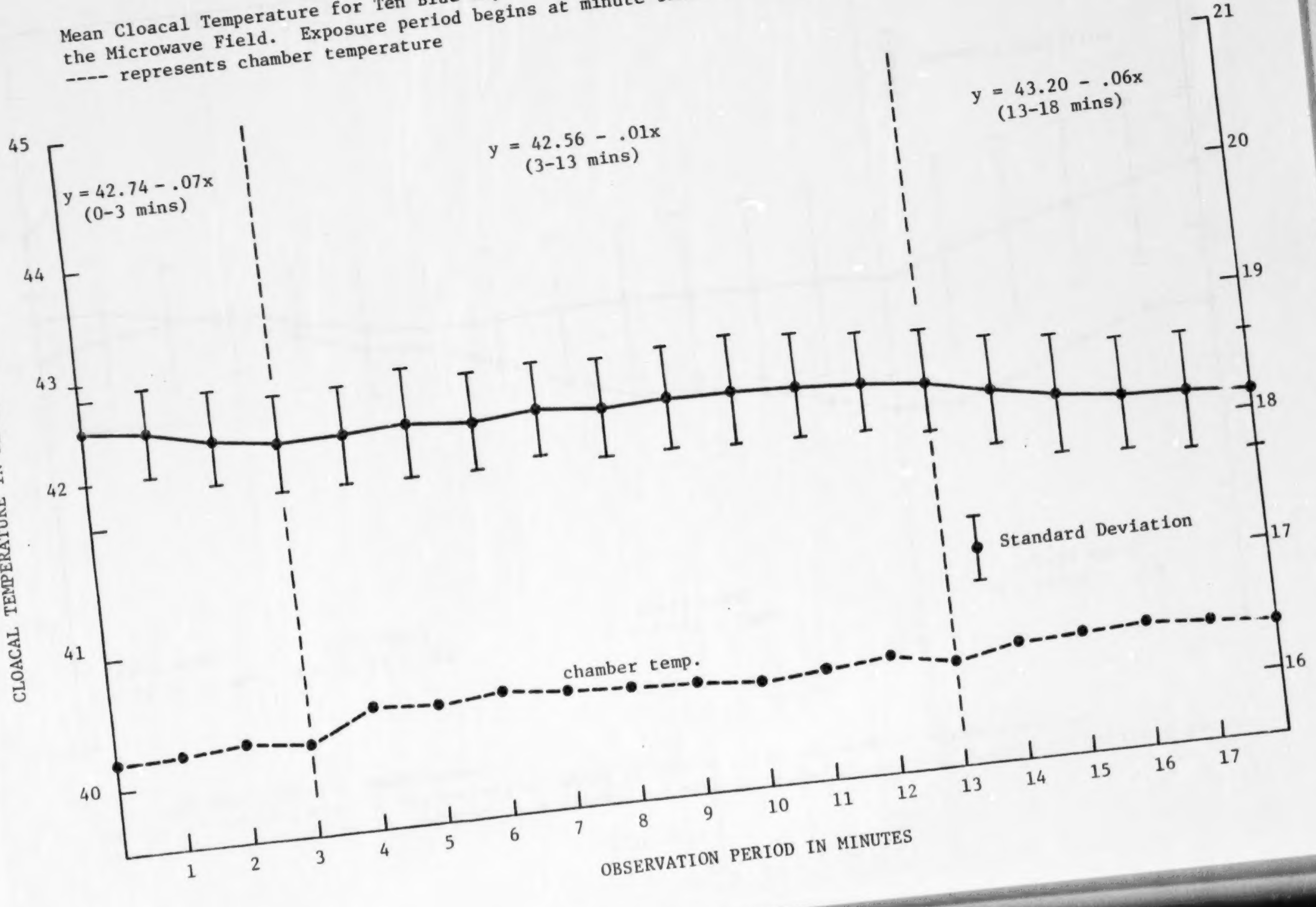


FIGURE 4-21

Mean Cloacal Temperature of Ten Blue Jays Irradiated with 25 mW/cm^2 Oriented Perpendicular to the Ξ Vector of the Microwave Field. Exposure period begins at minute three and ends at minute thirteen. ---- represents chamber temperature.

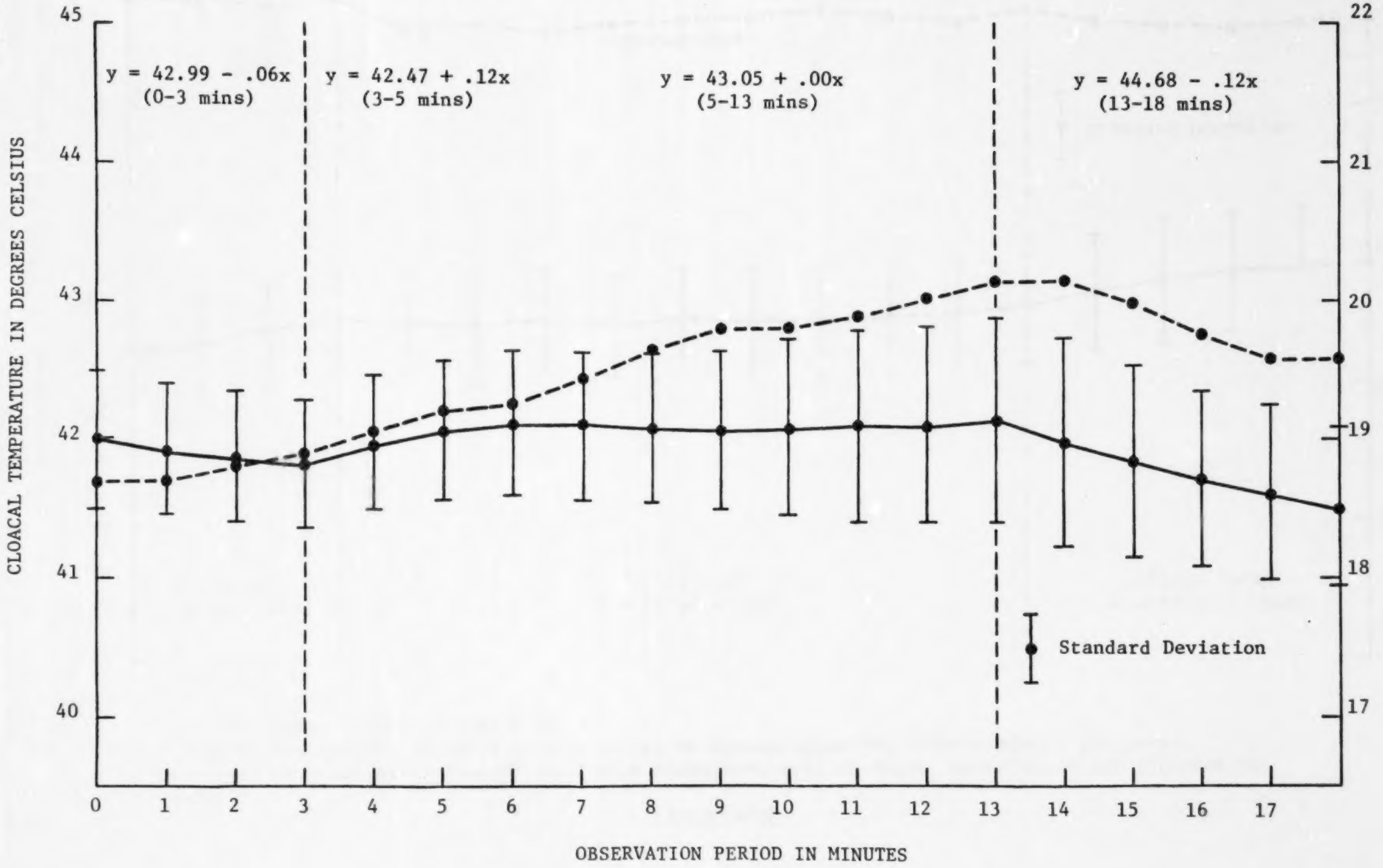


FIGURE 4-22

Mean Cloacal Temperature of Ten Blue Jays Irradiated with 25 mW/cm^2 Oriented Parallel to the E Vector of the Microwave Field. Exposure period begins at minute three and ends at minute thirteen.

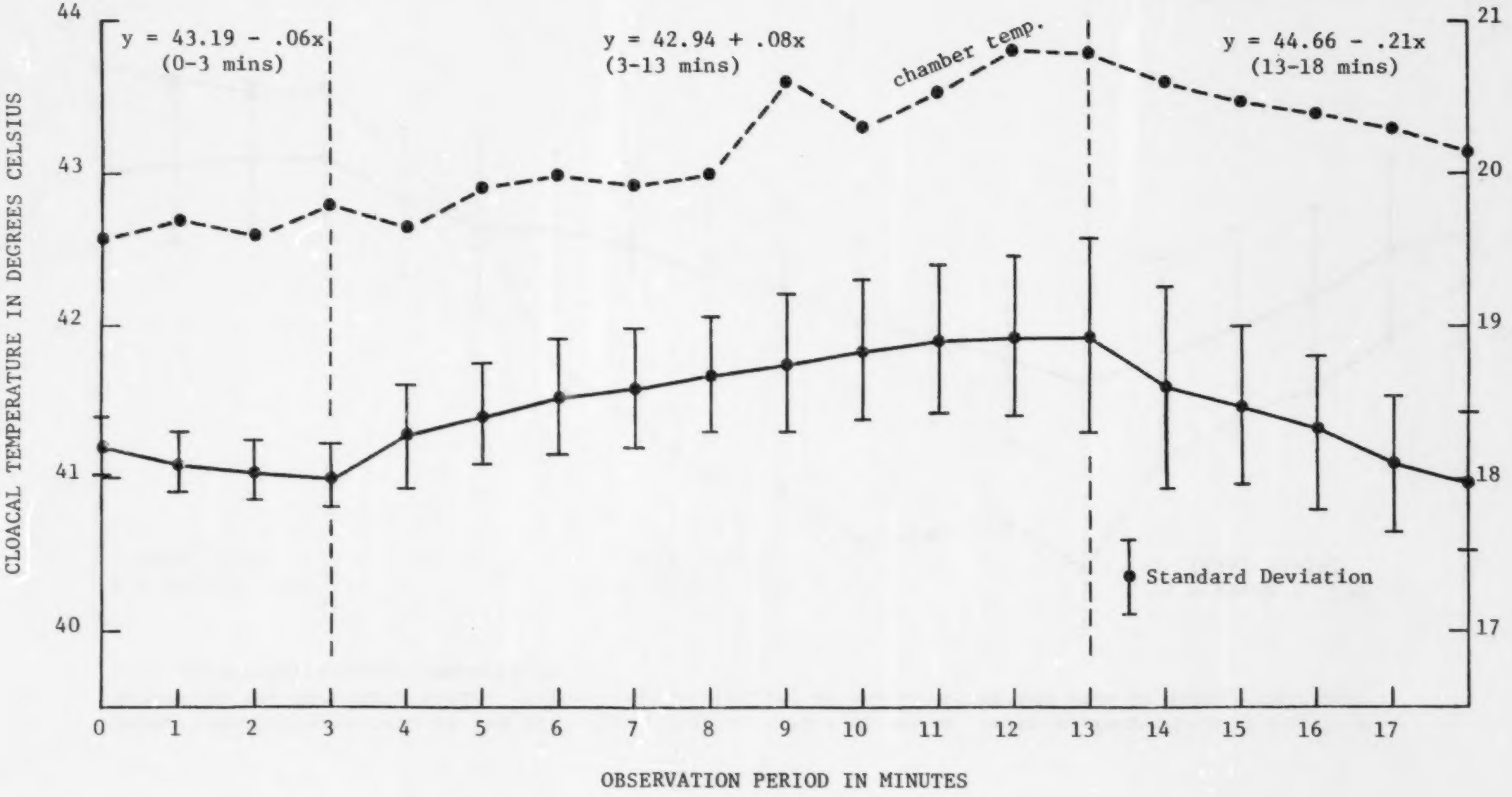


FIGURE 4-23

Mean Cloacal Temperature of Ten Blue Jays Irradiated with 50 mW/cm^2 Oriented Perpendicular to the E Vector of the Microwave Field. Exposure period begins at minute three and ends at minute thirteen. ---- represents chamber temperature.

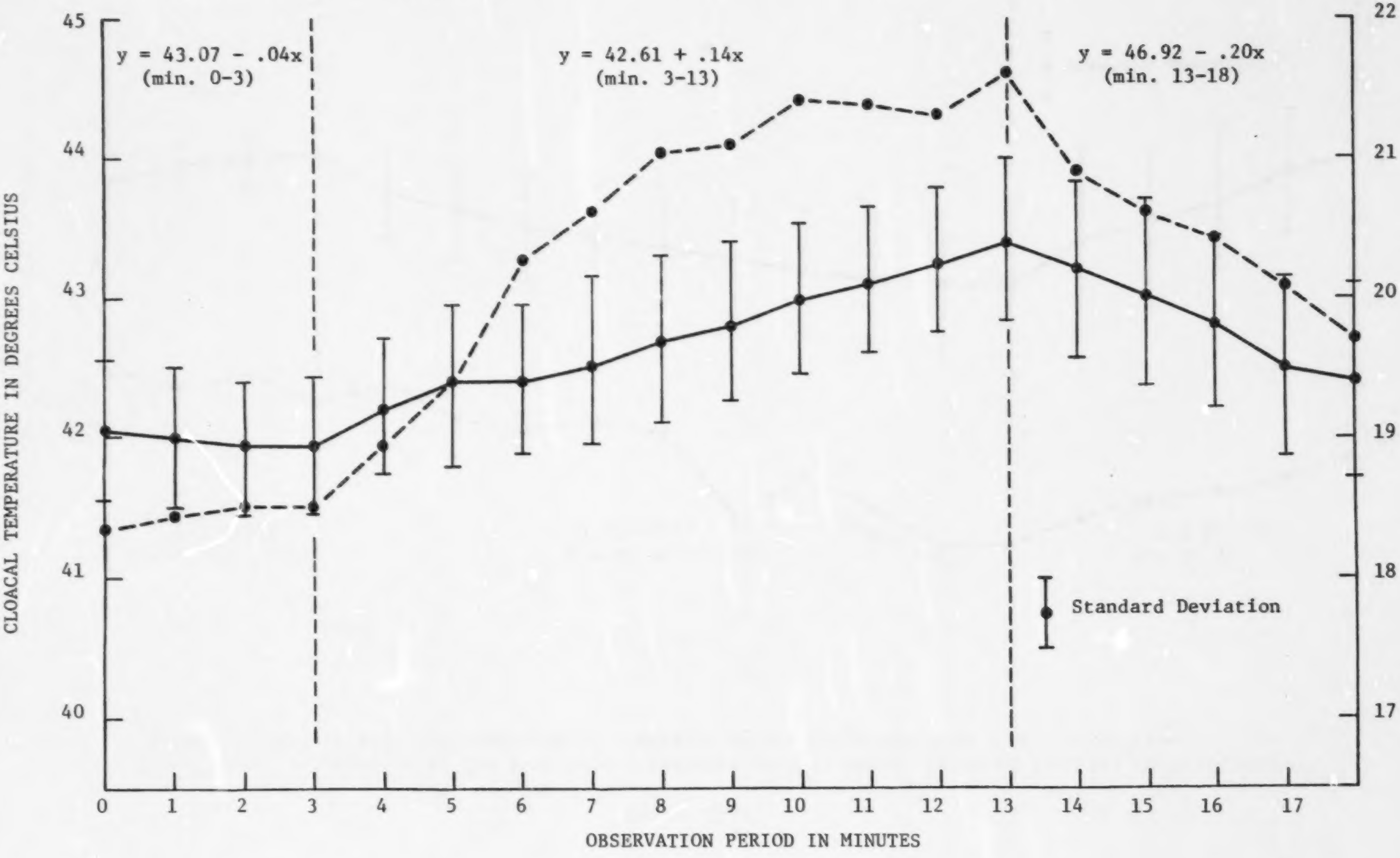


Table 4-20

Summary of Results and Conditions for Studies of Cloacal Temperature of House Finches and Blue Jays

				Bird Temperature			Chamber		Ambient		
Species	N	mW/cm^2 [(a)]	Orientation	$\bar{X}$ $T_{3\ min}$	$\bar{X}$ $T_{13\ min}$	$\bar{X}$ ΔT	$\bar{X}$ T_{max}	ΔT	$\bar{X}$ T	$\bar{X}$ RH%	Figure
House Finch	9	0	-------------	42.5°C	42.2°C	-.3	---	--	19.1°C	30	5
House Finch	10	25	perpendicular	41.5	41.3	-.2[(b)]	19.2	1.5	19.5	40	6
House Finch	10	25	parallel	42.1	42.3	.2[(c)]	21.5	1.5	20.0	43	7
House Fince	10	50	perpendicular	42.3	43.8	1.4	23.9	4.9	19.9	37	8
House Finch	5	50	parallel	42.6	46.9	4.4[(d)]	23.7	4.9	18.9	40	9
Blue Jay	10	0	-------------	43.5	43.2	-.3	---	--	19.3	44	11
Blue Jay	10	10	perpendicular	42.5	42.4	-.1	16.9	.1	19.1	36	12
Blue Jay	10	25	perpendicular	42.8	43.1	.3	21.1	1.5	19.4	54	13
Blue Jay	10	25	parallel	43.0	43.9	.9	22.8	1.3	20.8	56	14
Blue Jay	10	50	perpendicular	42.9	44.4	1.5	22.6	3.43	19.3	36	15

ΔT Chamber = change in chamber temperature from minute zero to minute 13

(a) mW/cm^2 = power density used; $T_{3\ min}$ = Cloacal temperature at start of irradiation; $T_{13\ min}$ = Cloacal temperature at termination of irradiation; ΔT = ($T_{3\ min}$ minus $T_{13\ min}$); T_{max} = maximum temperature of exposure chamber during irradiation; $T_{ambient}$ = ambient temperature; RH = relative humidity)

(b) The maximum cloacal temperature reached during exposure was 41.85° at minute 5, ΔT = .35°C.

(c) The maximum cloacal temperature reached during exposure was 42.6° at minute 6, ΔT = .5°C.

(d) Two of the five birds irradiated parallel at 50 mW/cm^2 after 9 minutes of exposure.

Experiments were conducted between 23 December 1980 and 3 April 1981.

4.4.2.3 Results and Discussions

4.4.2.4 House Finches

As shown in Figure 4-13, (individual data for each House Finch are presented in Appendices A4.4-1 to A4.4-5), a small but significant decline of 0.02^{o}/minute in cloacal temperature was observed in House Finches during 18 minutes of sham irradiation (control) ($F = 8.4$; d.f. = 1, 169; $P < 0.05$). Between T_3 and T_{13} minutes, the decrease was not significant ($F = 2.77$, d.f. = 1, 97; $P > 0.05$). The cloacal temperature of House Finches exposed to 25 mW/cm^2 perpendicular to the E vector of the field increased slightly during the first two minutes of irradiation ($F = 1.88$; d.f. = 1, 28; $P > 0.05$; Figure 4-14) (Appendix A4.4-2). During the remaining eight minutes of irradiation ($T_3 - T_{13}$) there was a significant body temperature decrease of 0.07^{o}/minute ($F = 5.69$; d.f. = 1, 88; $P < 0.05$). After termination of irradiation, the mean cloacal temperature continued to decrease gradually ($F = 1.43$; d.f. = 1.58; $P > 0.05$). When House Finches were oriented parallel to the E vector of the 25 mW/cm^2 field, cloacal temperature increased significantly during the first four minutes of irradiation ($F = 14.24$; d.f. = 1, 38; $P < 0.01$; minutes 3-6; Figure 4-15) (Appendix A4.4-3). Thereafter, cloacal temperature decreased at a significant rate of 0.04^{o}/minute ($F = 4.76$; d.f. = 1, 78; $P < 0.05$) until the termination of irradiation at which time body temperature decreased significantly more rapidly at a rate of 0.26^{o}/minute ($F = 42.77$; d.f. = 1, 58; $p < 0.001$; minutes 13-18).

During exposures of 50 mW/cm^2, the cloacal temperature of House Finches oriented perpendicular to the E vector increased continuously at a rate of 0.12^{o}/minute ($F = 67.44$; d.f. = 1, 108; $P < 0.001$; for minutes 3-10; refer to Figure 4-16) (Appendix A4.4-4). After termination of irradiation, cloacal temperature decreased at a significant rate of 0.35^{o}/minute ($F = 54.66$; d.f. = 1, 58; $P < 0.001$; minutes 13-18). When House Finches were oriented parallel to the E vector of the 50 mW/cm^2 field, cloacal temperatures increased rapidly at a rate of 0.41^{o}/minute ($F = 107.77$; d.f. = 1, 53; $P < 0.001$ for minutes 3 to 13; refer to Figure 4-16) (Appendix A4.4-5). Two of the five individuals irradiated in the parallel position died after nine minutes of irradiation (T_{12}) at which time their body temperatures had reached 46.7 and 47.3°C, respectively. Final temperatures (T_{13}) for these two birds were obtained by extrapolations of their respective regression equations used on constructing temperature profile curves. After termination of 50 mW/cm^2 irradiation, cloacal temperature of birds oriented parallel to the E field vector decreased rapidly at a rate of 0.60^{o}/minute ($N = 2$; $F = 66.32$; d.f. = 1, 10; $P < 0.001$; for minutes 13-18). House Finches exposed at 50 mW/cm^2 and oriented in a parallel position to the E vector displayed a significantly more rapid increase in cloacal temperature than did birds oriented perpendicular to the E vector and exposed to the same microwave level ($F = 8, 10$; d.f. = 1, 61; $P < 0.001$).

Temperature - time profiles of sham treated House Finches indicate that the changes associated with handling and restraining birds does not contribute to any noticeable rise in cloacal temperature during irradiation.* Cloacal temperature profiles of irradiated birds show a similar pattern for all treatments; an initial rise in temperature during the first two to four minutes of irradiation. Whether temperature continues to increase, levels off, or decreases depends upon both the power density used, and the orientation of the bird's body with respect to the E vector of the microwave field. The results of regression analysis of temperature - time profiles for House Finches exposed to 25 and 50 mW/cm^2 (Appendix A4.4-6) suggest that, even while restrained in a mesh, House Finches are capable of some thermoregulatory response to compensate for the heating due to microwave irradiation. A positive and significant slope for the body temperature -- profile curve (25 mW/cm^2, parallel, minutes 3-6; 50 mW/cm^2, perpendicular, minutes 3-13; 50 mW/cm^2, parallel, minutes 3-13, Appendix A4.4-7) shows that the bird is being heated by the microwave irradiation. A negative and significant slope in the temperature curve during irradiation (25 mW/cm^2, perpendicular, minutes 5-13; 25 mW/cm^2, parallel, minutes 6-13) shows that House Finches are probably compensating for the heating effect of irradiation. Where temperature curves show a significant slope after termination of irradiation (25 mW/cm^2 parallel, minutes 13, 18; 50 mW/cm^2, perpendicular, minutes 13-18; 50 mW/cm^2, parallel, minutes 13-18), the decrease in cloacal temperature is probably due largely to the removal of heat inducing microwave irradiation with thermoregulatory responses

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*In some cases, the decrease in pre-exposure temperature is significant. This results when insufficient time was allowed for stabilization of cloacal temperature before monitoring is begun.

(panting and gaping) contributing to the rate of decrease. The residual decrease in temperature after termination of microwave irradiation suggests that at least some of the mechanisms invoked to increase the rate of heat loss have a persistent character and remain active after the heat stress has ended. This is particularly evident in the temperature profile for House Finches irradiated parallel to the E vector of the 25 mW/cm^2 field (Figure 4-13). During minutes 6-13 of the irradiation period, cloacal temperature decreases at a significant rate of 0.04°/minute ($F = 4.76$; d.f. = 1, 78; $P < 0.05$). With the removal of the microwave irradiation, temperature decreases more rapidly, at a rate of 0.26°/min (minutes 13-18; $F = 42.78$; d.f. = 1, 58; $P < 0.001$).

House Finches oriented parallel to the E vector of the fields show greater increase in cloacal temperature than birds oriented perpendicular to the E vector (Table 4-20). The substantial difference between T for House Finches oriented perpendicular to the 50 mW/cm^2 field and that for House Finches oriented parallel to the field is interesting when the similarity of the chamber temperature is considered (Figure 4-18). While the change in chamber temperature during the irradiation is the same for both treatments, the increase in mean cloacal temperature during irradiation is significantly greater when birds are oriented parallel to the field. This observation demonstrates that when birds are oriented parallel to the field, cloacal temperature increases in response to some aspect of microwave irradiation other than that which simply raises ambient chamber temperature. When birds are oriented parallel to the 50 mW/cm^2 field, the rate of increase of cloacal temperature is so high as to be lethal for some individuals after only nine minutes of irradiation.

The pattern of change in House Finch cloacal temperature during irradiation is consistent with the results obtained in the studies of thermoregulatory behavior. In those studies, House Finches showed negligible response to irradiation at 25 mW/cm^2 when birds perched perpendicular to the field. Cloacal temperature profiles illustrate that House Finches oriented perpendicular to the E vector of the 25 mW/cm^2 field are able to dissipate the slight heat gain while restrained in a mesh envelope. Unrestrained House Finches can probably prevent a rise in temperature induced by 25 mW/cm^2 microwaves without observable thermoregulatory activities.

At 50 mW/cm^2, House Finches exhibited moderate thermoregulatory stress as evidenced by their behavior (Figure 4-10). Birds showed signs of stress within the first two minutes of irradiation, the period during which House Finch cloacal temperature increases most rapidly (Figure 4-16). Behavioral responses continued for the duration of exposure, indicating that House Finches use thermoregulatory postures to dissipate heat from microwave irradiation, and prevent body temperature from rising too rapidly. A more rigorous comparison of the thermoregulation and temperature regulation experiments is not possible due to several important differences in test conditions. First, the mean ambient temperature was 24.0°C during the studies of thermoregulatory behavior, and was 19.9°C during the temperature regulation experiments. Secondly, House Finches in the temperature regulation studies were restrained in a manner that reduced their thermoregulatory capabilities. Actual cloacal temperatures of non-restrained birds may be lower than these recorded during temperature regulation studies.

4.4.2.5 Blue Jays

Temperature profiles for all treatments of Blue Jays are illustrated in Figures 4-19 through 4-23. Mean cloacal temperatures $T_{3\ min}$ and $T_{13\ min}$ as well as T, ambient temperature, and relative humidity are presented in Table 4-20. Individual data for each bird are presented in Appendices A4.4-7 through A4.4-11.

Cloacal temperatures for ten sham treated Blue Jays decreased slightly at a rate of 0.03°/minute throughout the 18 minute observation period ($F = 29.6$; d.f. = 1, 188; $P < 0.05$ min 1 - 18; Figure 4-19 (Appendix A4.4-7). Between minutes 3 and 13, the decrease was not significant ($F = 3.71$; d.f. = 1, 108; $P > 0.05$). When Blue Jays were irradiated perpendicular to the 10 mW/cm^2 microwave field, cloacal temperature again decreased at a rate of 0.03°/minute during the 18 minute observation period ($F = 26.10$; d.f. = 1, 188; $P < 0.05$; minutes 1-18; Figure 4-20 (Appendix A4.4-8). There was no significant decrease in cloacal temperature during the 10 minute irradiation period itself ($F = 0.23$; d.f. = 1, 108; $P > 0.05$; minutes 3-13). When Blue Jays were irradiated perpendicular to the 25 mW/cm^2 field, temperature increased slightly during the first two minutes of irradiation ($F = 1.26$; d.f. = 1, 28; $P > 0.05$; minutes 3-5; Figure 4-21) (Appendix A4.4-9). For the remainder of the irradiation period, cloacal temperature remained constant ($F = 0.035$; d.f. = 1, 88; $P > 0.05$; minutes 5-13; Figure 4-21). After termination of the irradiation, cloacal temperature decreased at a significant rate of 0.12°/minute ($F = 606$; d.f. = 1, 58;$P < 0.05$; minutes 13-18). When Blue Jays were oriented parallel to the 25 mW/cm^2 field, temperature increased significantly during irradiation at a rate of 0.08°/minute ($F=42.94$; d.f. = 1, 108; $P < 0.001$, minutes 3-13; Figure 4-22) (Appendix A4.4-10). After termination of irradiation, cloacal temperature decreased at a significant rate of 0.21°/minute ($F = 27.27$; d.f. = 1, 52; $P < 0.001$; minutes 13 18). During experimentation at 50 mW/cm^2, Blue Jays oriented perpendicular to the E vector of the microwave field showed a rate of cloacal temperature increase of 0.14°/minute ($F = 73.90$; d.f. = 1, 108; < 0.001; Figure 4-23) (Appendix A4.4-11). Blue Jays were not tested while oriented parallel to the 50 mW/cm^2 field because of the harmful effect this would have had on the birds.

As seen with House Finches, temperature profiles of sham treated Blue Jays indicate that handling and restraint do not contribute to increased cloacal temperature during irradiation. For all treatments of Blue Jays except the 10 mW/cm^2 irradiation, cloacal temperature increased during the first two to four minutes of irradiation after an initial decrease during the pre-exposure period (0-3 minutes)* The continued increase or subsequent decrease of cloacal temperature depended on both the power density in use and the orientation of a bird's body with respect to the E vector of the microwave field. Results of the regression analyses of temperature - time profiles for Blue Jays (Appendix A4.4 12) indicate that Blue Jays are also capable of some thermoregulatory control while restrained in the mesh holder during irradiation. Cloacal temperature curves show significant increases in mean temperature due to microwave irradiation during only two treatments (25 mW/cm^2, parallel, minutes 3-13; and 50 mW/cm^2, perpendicular, minutes 3 13) (Appendix A4.4-12).

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*In some cases, the decrease in pre-exposure temperature is significant. This results when insufficient time is allowed for stabilization of cloacal temperature before monitoring is begun.

Blue Jays oriented perpendicular to the E vector showed no significant decrease in cloacal temperature during minutes 5 to 13 of irradiation at 25 mW/cm^2 (Figure 4-21). On termination of the 25 mW/cm^2 (perpendicular) irradiation, cloacal temperature decreased at a significant rate suggesting that Blue Jays were able to maintain this stable cloacal temperature using thermoregulatory behavior (gaping and panting) which then contributed to the rate of decrease in post-exposure temperature. Similarly, the significant rates of decrease in post-exposure cloacal temperature for the 25 mW/cm^2 (parallel) and 50 mW/cm^2 (perpendicular) treatments probably result from both the removal of microwave irradiation and some thermoregulatory activity of the birds.

The cloacal temperature changes observed in irradiated Blue Jays are consistent with the behavioral results of the thermoregulatory response experiments. During irradiation with 10 mW/cm^2 microwaves, Blue Jays showed no signs of thermoregulatory stress (Table 4-19) nor was there any increase in cloacal temperature during a ten minute irradiation period. At 25 mW/cm^2, Blue Jays showed moderate thermoregulatory stress as evidenced by their behavior (Figure 4-11). Temperature profiles of Blue Jays irradiated at 25 mW/cm^2 perpendicular to the E vector of the field show very little change in cloacal temperature after a slight increase during the first two minutes of irradiation. Presumably, unrestrained Blue Jays are able to offset the heating effects of 25 mW/cm^2 by using thermoregulatory postures, and thus maintain a stable body temperature during irradiation for ten minutes.

When irradiated at 50 mW/cm^2, Blue Jays showed considerable thermoregulatory stress (Figure 4-12) as well as a significant rise in cloacal temperature (Figure 4-23). Blue Jays continued to show thermoregulatory behaviors for five minutes after the termination of irradiation; cloacal temperatures of restrained Blue Jays did not return to pre-exposure level ($T_{3\ min}$) within the five minute post-exposure monitoring period. It seems clear that 50 mW/cm^2 irradiation causes substantial elevation of body temperature in Blue Jays such that they cannot maintain a stable body temperature during irradiation. Again, experimental conditions prevented any further comparison of behavioral and temperature responses of Blue Jays to microwave irradiation.

4.4.3 Summary and Conclusions

The results of both the behavior and temperature response studies suggest the following relationships between microwave irradiation and the thermoregulatory condition of House Finches and Blue Jays.

(1) House Finches and Blue Jays show behavioral reponses to microwave induced heat stress which are good indicators of changes in cloacal temperatures during microwave irradiation.

(2) For both species, studies of behavior and cloacal temperature indicate that there is no observable thermoregulatory stress induced by microwave irradiation of 10 mW cm^2 or less.

(3) House Finches are only slightly stressed by irradiation with 25 mW/cm^2, while Blue Jays exhibit an increase in cloacal temperature and in thermoregulatory behavior. This suggests that bird species of body mass equal to or greater than that of Blue Jays (85 g) will experience some degree of thermal stress when exposed to a 25 mW/cm^2 microwave field.

(4) At 50 mW/cm^2, both House Finches and Blue Jays experience thermal stress and show significant elevation in cloacal temperature during 10 minutes of irradiation. While ΔT was the same for both species (1.44°C for House Finches and 1.47° C for Blue Jays), Blue Jays showed an elevated behavioral response suggesting that they must expend more energy than House Finches to prevent a greater rise in cloacal temperature.

(5) The orientation of a bird's body with respect to the E vector of the microwave field is an important factor in determining the magnitude of thermal stress. Both House Finches and Blue Jays experienced significantly greater elevation in cloacal temperature when the longitudinal axis of the body was oriented parallel to the E vector than when oriented perpendicular to the E vector. At 50 mW/cm^2, parallel orientation proved lethal for some House Finches after nine minutes of irradiation.

(6) Behavioral observations and regression analyses of temperature profiles indicate that for both House Finches and Blue Jays, the decrease in cloacal temperature after termination of irradiation is due, in part, to continued thermoregulatory activities which facilitate the reduction in cloacal temperatures to pre-exposure levels.

REFERENCE

Altmann, J. 1974. Observational study of behavior: sampling methods. Behavior 49: 227-267.

4.5 MOLT OF BIRDS EXPOSED TO MICROWAVE RADIATION (110 TO 150 DAYS)

4.5 Molt of Birds Exposed to Microwave Radiation (110 to 150 Days)

4.5.1 Introduction

Molt was chosen as a sensitive indicator of the possible deleterious effects of microwave irradiation on the endocrine and autonomic nervous systems of birds. Molt is a complex mechanism of cyclic (often annual) ecdysis and endysis of feathers. The timing of molt is related to the seasons of breeding and migration: According to Thomson (1964), "the cylical occurrence of molt is determined by intrinsic (physiological) factors in which the thyroid and hypothalmic - pituitary - gonadal systems are principally concerned, activated also by extrinsic (physical) influences. Of the latter, day length appears to be the most important, but temperature also contributes."

Molt is genetically controlled within a given species or larger taxonomic grouping and normally falls into a rigid time frame. Molt begins a fixed number of days after the breeding activity (for adults) or fledging (for juveniles). It usually ends before fat deposition and fall migration or before winter fat deposition in northern non-migratory species (Stresemann, 1966)

A significant interruption or retardation of molt induced by exposure to microwave fields could have a detrimental effect on the bird's survival. A delay or failure to molt flight feathers (which is triggered to a great extent by day length) could result in an inability of the bird to participate successfully in long migratory flights. Similarly, non-migrant species without a normal molt would be less well equipped to cope with cold weather during northern winters. Another adaptive factor in avian survival is the loss of brightly colored plumage via the adult postnuptial molt which produces a more cryptic non-breeding plumage that is less obvious to predators. Molt, therefore, is a critical factor affecting a bird's ability to adapt to its environment and thus serves as a sensitive indicator of altered physiology.

It is reasonable to postulate that the proposed rectenna configuration will not provide suitable sites for bird's nests or roosts above or among the active rectenna elements, i.e., in areas subject to field strengths of greater than 1 mW/cm^2. These locations would lack shelter from climatic extremes and airborne predators. We expect that nesting or roosting will more likely occur beneath the active elements, or within and among the support and alignment structures and that only birds in flight across the rectenna would be exposed to power densities greater than 1.0 mW/cm^2. Unless faced with strong headwinds, birds flying at 30 km/h should not be exposed to power densities greater than 1.0 mW/cm^2 for more than 30 minutes.

The original protocol of June 1980 is shown below.

First Year	Expose adult House Finches (Carpodacus mexicanus) continuously to field strengths of 0 (control, 0.1, 1.0 and 10 mW/cm^2) throughout the major prebasic (post-nuptial) molt.

Second Year   Evaluate the results of the first year and design the experiments accordingly.

(a) If the first year's study showed no detectable differences between irradiated and non-irradiated (control) birds, experiments would be repeated with larger samples at 0, 10 and 25 mW/cm^2 or higher power densities.

(b) If the first experiment showed differences between control and microwave-exposed birds, we would design new studies, as needed, using larger samples, and try to understand the mechanisms by which microwaves influenced molting. We would also investigate effects of microwave on other species of birds.

The molting House Finches were initially studied to answer the following:

-- Will microwave exposures alter molting of birds that are exposed while nesting in areas immediately adjacent to the proposed rectenna site?

4.5.2 Methods

Following its introduction to the Northeastern United States in 1940 (Griscom and Snyder, 1955), the House Finch has become a year-round resident. The adult prebasic molt is complete and typical of resident passerines (Dwight, 1900). In southeastern Massachusetts, the resident, non-migrant House Finches have one complete molt between the end of June and December.

Twenty-one adult birds with worn plumage and brood patches (females) or cloacal protuberances (males) were trapped before the onset of prebasic molt with the exception of five birds which had just started to actually molt. Trapping sites were Chatham, Plymouth and Rockport, Massachusetts. Individually numbered plastic legbands were applied to each bird. The finches were housed in rectangular microwave transparent cages 1 x 1 x 0.5 m that were divided into four separate cells, each containing one or two birds. Cages were placed in either microwave exposure chambers or in control chambers. Initial experiments concentrated on differentiating responses between the control and 10 mW/cm^2 exposure groups in order to provide data of highest relevance to the SPS system. The sample sizes of birds could not be increased beyond 10 animals because most of the space in the chamber was already committed to other experiments. These reasons and our inability to obtain adequate numbers of birds at the critical time (before onset of molt) precluded conducting experiments at 0.1 mW/cm^2 and reduced the number of birds available for exposure to levels of 1 mW/cm^2.

Numbers of House Finches and Exposure Levels

Exposure (mW/cm^2)	0	1	10	25
Number of Birds	5	2	10	2

We proposed initially to expose representative numbers of birds to 25 mW/cm^2 until two problems were encountered. Firstly, there was a delay in completion of the 25 mW/cm^2 chamber. Waiting until the chamber was completed would have meant missing the first week or two of molt at the end of June and early July. Secondly, in early July, House Finches placed in a nonfunctioning exposure chamber exhibited gaping behavior from hyperthermia within an hour when ambient temperatures were greater than 30°C.

Additionally, there was a small likelihood of birds being exposed to 25 mW/cm^2 on a continuous basis at a rectenna site. For these reasons, we chose to use 10 mW/cm^2 exposures for the major sample and delayed the 25 mW/cm^2 exposures until later in the season (4 September) when ambient temperatures are lower. At this time, two birds that had already started molting were included in the 25 mW/cm^2 experiment. The animals were exposed continuously, except for times of cage maintenance, e.g., cleaning, feeding, water replacement, for a period ranging between 110 and 150 days.

Artificial lighting was controlled to simulate day length. A balanced diet of water, seeds, fresh fruit, vegetables and mealworms was given daily, perches were provided and cages were cleaned daily. The ambient or room temperature where the controls were kept typically ranged between 21 and 32°C during a mid-summer day in 1980, between 20 and 24°C during the fall and was held at 18°C during November and December. All birds acclimated satisfactorily and, with one exception, survived to completion of the experiment.

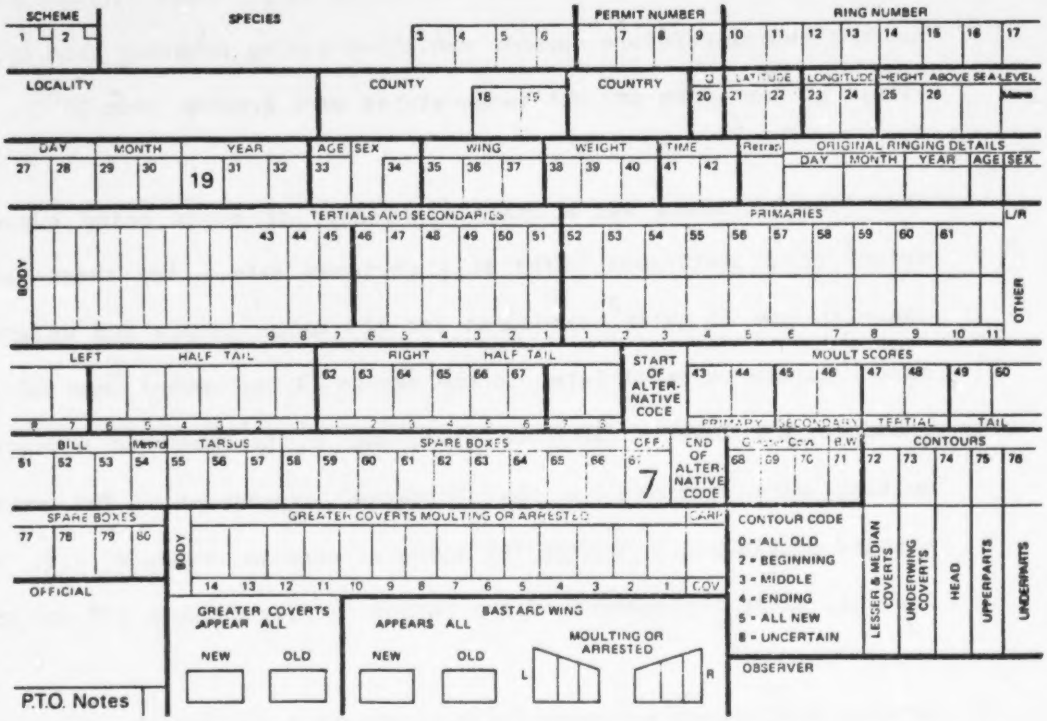
The following data were collected for each bird every 7 to 13 days from 30 June to 5 December 1980 and recorded on molt cards (see Figure 4-24).

1. Band number

Figure 4-24. Molt Recording Form

Reproduced from best available copy.

Molt Record Card



SCHEME 1 2 | SPECIES 3 4 5 6 | PERMIT NUMBER 7 8 9 | RING NUMBER 10 11 12 13 14 15 16 17

LOCALITY | COUNTY 18 19 | COUNTRY | Q 20 | LATITUDE 21 22 | LONGITUDE 23 24 | HEIGHT ABOVE SEA LEVEL 25 26 Metres

DAY 27 28 | MONTH 29 30 | YEAR 19 31 32 | AGE 33 | SEX 34 | WING 35 36 37 | WEIGHT 38 39 40 | TIME 41 42 | Retrap | ORIGINAL RINGING DETAILS DAY MONTH YEAR AGE SEX

BODY | TERTIALS AND SECONDARIES 43 44 45 46 47 48 49 50 51 (9 8 7 6 5 4 3 2 1) | PRIMARIES 52 53 54 55 56 57 58 59 60 61 (1 2 3 4 5 6 7 8 9 10 11) | L/R | OTHER

LEFT HALF TAIL (8 7 6 5 4 3 2 1) | RIGHT HALF TAIL 62 63 64 65 66 67 (1 2 3 4 5 6 7 8) | START OF ALTERNATIVE CODE | MOULT SCORES 43 44 PRIMARY 45 46 SECONDARY 47 48 TERTIAL 49 50 TAIL

BILL 51 52 53 | Method 54 | TARSUS 55 56 57 | SPARE BOXES 58 59 60 61 62 63 64 65 66 | CFF. 67 7 | END OF ALTERNATIVE CODE | Greater Cov. 68 69 70 | B.W. 71 | CONTOURS 72 73 74 75 76

SPARE BOXES 77 78 79 80 | BODY | GREATER COVERTS MOULTING OR ARRESTED (14 13 12 11 10 9 8 7 6 5 4 3 2 1) | CARP. COV.

CONTOUR CODE
0 = ALL OLD
2 = BEGINNING
3 = MIDDLE
4 = ENDING
5 = ALL NEW
8 = UNCERTAIN

LESSER & MEDIAN COVERTS | UNDERWING COVERTS | HEAD | UPPERPARTS | UNDERPARTS

OFFICIAL

GREATER COVERTS APPEAR ALL: NEW ☐ OLD ☐

BASTARD WING: APPEARS ALL: NEW ☐ OLD ☐ | MOULTING OR ARRESTED L R

OBSERVER

P.T.O. Notes

BRITISH TRUST FOR ORNITHOLOGY MOULT RECORD CARD

General Instructions

Note that this card serves for both passerines and non-passerines. Complete one card for each bird showing active or 'arrested' moult, bearing in mind that handling time should be kept to a minimum. Treat recaptures as new birds except on same day. Ensure vital data such as species and date are completed. Please observe the following priorities: (1) Species, date, county (locality), co-ordinates, observer, primaries. Items in (1) are essential on all cards. (2) Secondaries, tertials, weight and time. (3) Tail. (4) Greater coverts, alula and carpal covert. (5) Contour feathers. DO NOT WRITE ANYTHING IN THE SHADED BOXES.

Detailed Explanations and Instructions

Q = Quadrant. Northern hemisphere west of Greenwich = 7; East of Greenwich = 1; Southern hemisphere (Africa) = 3.

Height above sea level: Convert feet to metres as follows: feet x 3, ÷ 10 approx. = metres.

Feather scoring: 0 = Old feather remaining; 1 = old feather missing or new feather completely in pin; 2 = new feather *just* emerging from sheath or up to ⅓ grown; 3 = new feather between ⅓ and ⅔ grown; 4 = new feather from ⅔ grown to fully grown *but* with remains of waxy sheath persisting; 5 (not N) = new feather fully developed with no trace of sheath remaining at base; 8 = full grown feather, age uncertain. If feather not examined, leave blank.

If moult is not in phase, please record both wings and in any case label which row of boxes applies to which wing.

N.B. The outermost, tenth, primary ('first' in 'The Handbook') is reduced in many passerine families, e.g. larks, hirundines, wagtails, pipits, Waxwing, Bearded Tit, finches and buntings. In these, the tenth and eleventh primary boxes should be completed with a cross joining the corners to show you have made allowance for this fact; neglect of this point may make the use of the card for analysis impossible. In other families, all the primaries should be scored.

Bill: Method of measurement. The following code should be used in box labelled 'method': Tip to feathers = 1; tip to skull = 2; tip to cere = 3; any other method = 4.

Contour feathers: The method of recording these is explained on the card.

Greater Coverts and Alula (Bastard Wing): If there is no active moult of the greater coverts, please tick the appropriate box (New or Old). If they are moulting or of mixed age (arrested), please record if possible as for primaries. As a briefer alternative, the following coding is permissible 0 = Old; 5 = New; X = missing or growing; 8 = Full-grown but uncertain age; blank = not examined. Where wings are out of phase, boxes may be divided horizontally and labelled L and R.

Carp. Cov.: (Carpal Covert). Scoring as for greater coverts. This feather lies between the outer end of the secondary greater covert row and the alula and care should be taken not to confuse it with a partly grown outermost greater covert.

Completed cards should be returned as soon as possible, in Wetmore and ring number order together with the completed summary form supplied with each batch of cards. The address from which cards may be obtained and to which they should be returned is 'Moult Enquiry', B.T.O., Beech Grove, Tring, Herts, HP23 5NR.

For those planning moult studies, the B.T.O. Field Guide No. 11, 'A Guide to Moult in British Birds' by D. W. Snow is indispensable; obtainable from B.T.O. Moult-cards for private use may be obtained for 1 p each.

NOTES

2. Cage and cell number

3. Microwave exposure (and date of commencement)

4. Card number

5. Date

6. Sex (Wood, 1969)

7. Cloacal protuberance or brood patch development (as indications of breeding condition, see Svensson (1970), Salvadori and Youngstrom (1973).

8. Total Molt Scoring. The molt card is based on the one used by the British Trust for Ornithology, see Snow (1967). Snow's numbering, sequences, and definitions are used. Following the standard "molt score" system used by Evans (1966) old remiges and rectrices were scored zero; one for feathers absent or in pin; two, three, and four for various stages of growth; and five for complete new feathers.

   The scoring system used ranged from a minimum score of zero (no feather loss) to a maximum score of 240 (full or total molt) as shown below:

- Primaries 90 (18 major feathers x 5)

-- Secondaries 60 (12 major feathers x 5)

-- Tertials 30 (6 major feathers x 5)

-- Tails 60 (12 major feathers x 5)

Total Maximum Score 240

The score from the feathers of the bird's right side was multipled by 2 to produce the total molt score for that animal, as it was assumed that the normal course of molt was symmetrical (Snow, 1967). The total scores from periodic observations were plotted against data to indicate speed and timing of molt (Newton, 1967; Snow, 1969).

9. Flight feather length measurements. The feathers chosen are (with a few exceptions due to wear or accidental loss) the left side primaries (PP) numbers 1, 4, 9; secondaries (SS) 1, 4; tertial (TT) 7; tail (TL) 1 and 6. The old, unmolted feathers were measured once from the base to tip with a dial vernier calipers to 0.1 mm. Feather loss was noted and all growing feathers measured periodically until completion of growth. Variability of length of old feathers may be introduced by normal wear, especially on the tail and perhaps primary 9.

On the first observation, birds were observed for any abnormalities and conventional measurements were taken of tail length, including flat and chord lengths of wings from carpal joint to the tip of the longest primary.

4.5.3 Results and Discussion

The dates of all observations for each bird as well as the combined scores for the nine major primary feathers on each wing, the six secondaries on each wing, three tertials on each wing, and the twelve rectrices or tail of each bird are summarized in Appendix A4.5-1. The total score, i.e., the sum of scores of each of the indicator feathers, is also presented.

In reviewing data for molt of flight feathers, several confounding factors were evident. Individual birds began and ended molting at different times and some birds had already started to molt when they were included in the experiment. It was therefore not possible to compute an average score for each of the different treatment groups.

It was also evident that data for the end of molting were more complete and, therefore, might be more useful as a common point of reference with which to combine molting of different birds within and among treatments. In those instances where molting was not complete (score of 240) at the last observation, the scores for the five previous observations were plotted against the corresponding observation time, and the curve extrapolated to where it intercepted the score of 240. This point was assigned a value of zero to represent the best estimate of the complete regrowth of the 48 indicator feathers or a score of 240. Scores obtained at each measurement for each bird were then plotted beginning at zero and continued back to the beginning of molt. Thus, days to completion of molt is plotted against the corresponding molt score. Since the times for each observation were different, the scores at 10 day intervals were obtained for each bird and the curves plotted. The time for 50% of the molt was determined for each bird and averaged. A second estimate of the time for 50% molt was obtained by averaging the individual molting scores at each time period for each of the treatments, plotting the mean scores and noting from the curve the time needed for 50% or time required for a molt score of 120 (last half of molt).

4.5.3.1 Controls

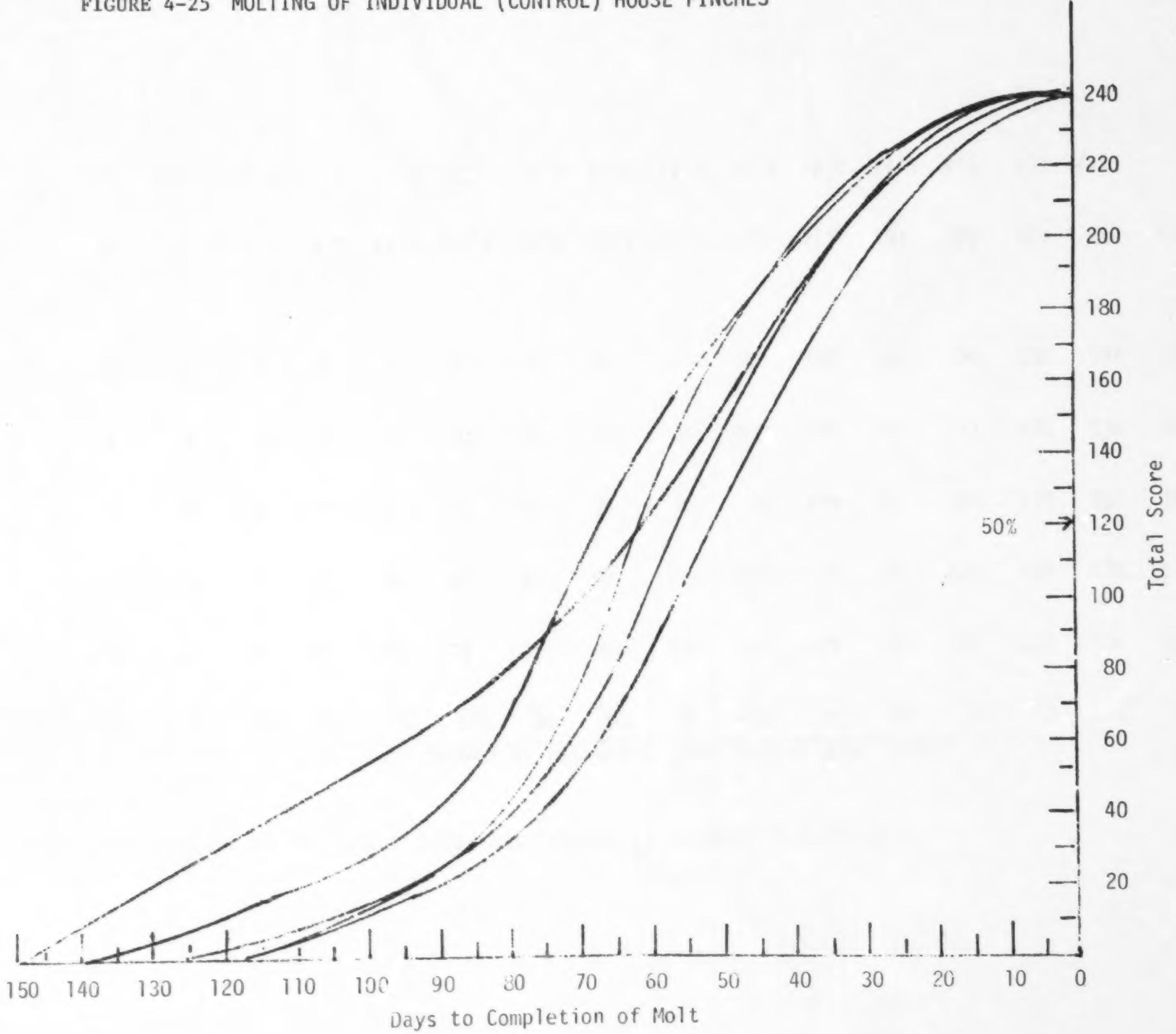
The individual curves for regrowth of flight feathers on five unexposed (control) birds are shown in Figure 4-25. It can be seen that the shape of the molt curve for flight feathers is sigmoid and that molting requires approximately 115 to 150 days. The mean time for the last half of molting is about 60 days.

Data on molting of each of the five unexposed birds, was tabulated in Table 4-21 and curves plotted in Figure 4-25. Table 4-21 contains the mean scores and standard deviation at each of the 10 minute time periods. From each of the curves plotted in Figure 4-25, the time required for each bird to achieve the last half of its molt (score of 120 to 240) was noted and the mean (59.6 days) and standard deviation (5.8 days) computed. The mean scores and standard deviation at each 10 minute interval for all 5 birds was also plotted. The time needed for the last half of molting was very close to the value obtained by averaging the values obtained from individual birds.

TABLE 4-21 MOLTING OF INDIVIDUAL BIRDS NOT EXPOSED TO MICROWAVES (CONTROLS)

	Time Needed for Half (score 120) to Full Molt (240)	Individual Scores at Different Times Before Molt (Days)															
		150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
G_2	62	0	10	20	32	42	54	66	82	100	125	154	183	206	215	236	240
G_3	67	0	0	4	12	20	27	42	66	108	145	174	197	215	228	236	240
G_5	56	0	0	0	2	11	19	28	38	60	98	144	180	208	228	238	240
G_6	61	0	0	0	0	7	17	26	43	76	128	169	198	217	230	239	240
G_{13}	52	0	0	0	0	7	15	21	32	52	86	126	164	196	220	234	240
$\overline{X}$	59.6	0	2	4.8	9.2	17.4	26.4	36.6	52.2	79.2	116	153	184	208	224	236	240
±SD	5.8	-	4.5	8.7	13.7	14.7	16.1	18.2	21.1	24.4	31.4	19.4	14.0	8.3	6.4	±1.9	

FIGURE 4-25 MOLTING OF INDIVIDUAL (CONTROL) HOUSE FINCHES



4.5.3.2 10 mW/cm^2

Data for individual birds exposed to 10 mW/cm^2 are provided in Table 4-22 and curves of individual birds plotted in Figure 4-26. Seven of the nine molting curves were sigmoid and similar in shape to control curves in that the scores were within 20 or 30 through the entire molting season. Based on values obtained from individual curves the mean and standard deviation for the last half of molting for 10 mW/cm^2 exposed birds is estimated to be 62.1 ± 7.3 days with full molting requiring 110 to 150 days. When the mean score at each time period was plotted the time for the last half of molting (50%) was found to be 61 days (Figure 4-29).

4.5.3.3 1 mW/cm^2 and 25 mW/cm^2

Two birds were exposed to microwave irradiation at 1 and 25 mW/cm^2. One of two birds exposed to 1 mW/cm^2 and both exposed to 25 mW/cm^2 were well into molting at the time they were included in the experiment as shown in Tables 4-23 and 4-24 and curves in Figures 4-27 and 4-28. While the shape of the curves for both birds at 1 mW/cm^2 resembled those (sigmoid) obtained for the controls and 10 mW/cm^2, the curves for the two 25 mW exposed animals were markedly different indicating either that rate of molting is slower for captive birds compared to birds in the wild, or else microwave delayed molting. Although there were too few animals at 25 mW/cm^2 for conclusive evidence, there is no indication of altered molting for the 1 and 10 mW/cm^2 as shown in Figure 4-29. An examination of the mean curves (Figure 4-29) reveals that with few exceptions all points on the curve for 1 and 10 mW/cm^2 exposed birds fell within plus or minus one standard deviation of

TABLE 4-22 MOLTING OF INDIVIDUAL BIRDS EXPOSED TO MICROWAVES AT 10 mW/cm²

Bird Ident.	Time Needed for Half Score (120) to Full Molt (240)	Individual Scores at Different Times Before Molt (Days)															
		150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
W2	77	0	8	16	24	37	56	84	112	138	164	185	204	216	226	234	240
G9	60	0	0	0	2	13	27	46	67	93	120	149	176	199	218	232	240
G15	54	0	0	0	2	13	26	43	62	82	105	133	161	187	210	228	240
G17	64	0	2	7	14	22	38	58	80	105	131	158	183	206	225	236	240
W51	52	0	0	0	0	0	2	11	28	54	90	128	162	191	217	232	240
G43	60	0	0	0	2	10	24	41	62	88	118	150	177	198	216	230	240
W44	65	0	3	11	22	35	51	70	90	115	131	153	173	194	212	227	240
W58	66	0	0	0	4	14	27	47	74	106	138	168	195	216	231	238	240
W57	61	0	0	0	5	16	31	47	67	91	120	154	184	209	229	238	240
$\overline{X}$	62.1	0	1.4	3.8	8.3	17.8	31.3	49.7	71.3	96.9	124	153.1	179.4	201.7	220.4	232.8	
SD	7.3	0	2.6	6.1	9.2	11.9	15.9	20.3	22.8	23.3	20.8	17.0	14.1	10.6	7.5	4.0	

FIGURE 4-26 MOLTING OF INDIVIDUAL BIRDS EXPOSED TO MICROWAVES AT 10 mW/cm^2

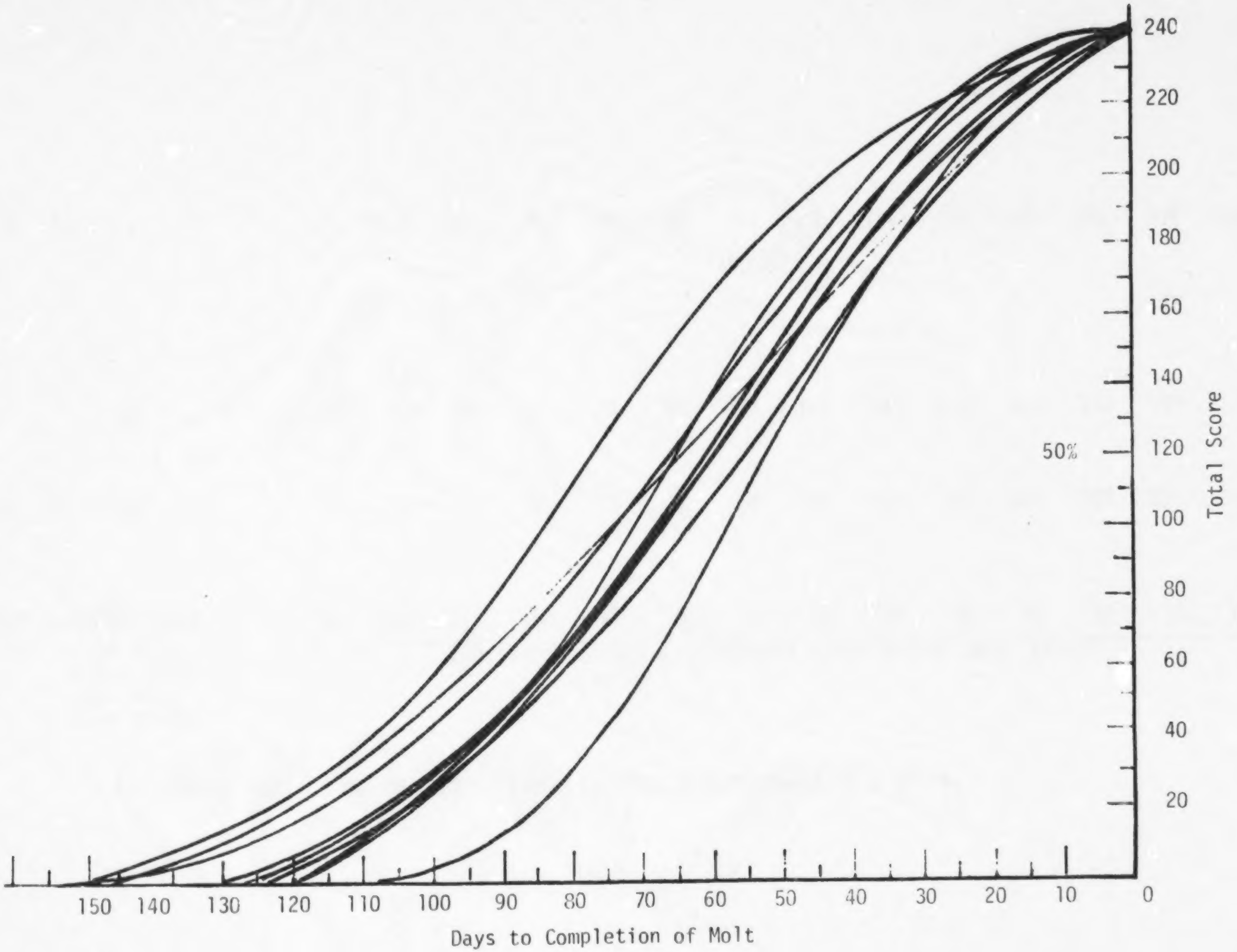


TABLE 4-23 MOLTING OF INDIVIDUAL BIRDS EXPOSED TO MICROWAVES AT 1 mW/cm^2

Bird Ident.	Time Needed for Half Score (120) to Full Score (240)	Individual Scores at Different Times Before Molt (Days)													
		130	120	110	100	90	80	70	60	50	40	30	20	10	0
G22	57	0	2	6	12	22	39	70	108	145	178	205	225	237	240
W56	79	39	45	60	80	99	120	144	166	186	204	217	228	235	240
$\bar{X}$	68	20	23.5	33	46	60	80	107	137	166	196	211	227	236	240

FIGURE 4-27 MOLTING OF INDIVIDUAL BIRDS EXPOSED TO MICROWAVES AT 1 mW/cm^2

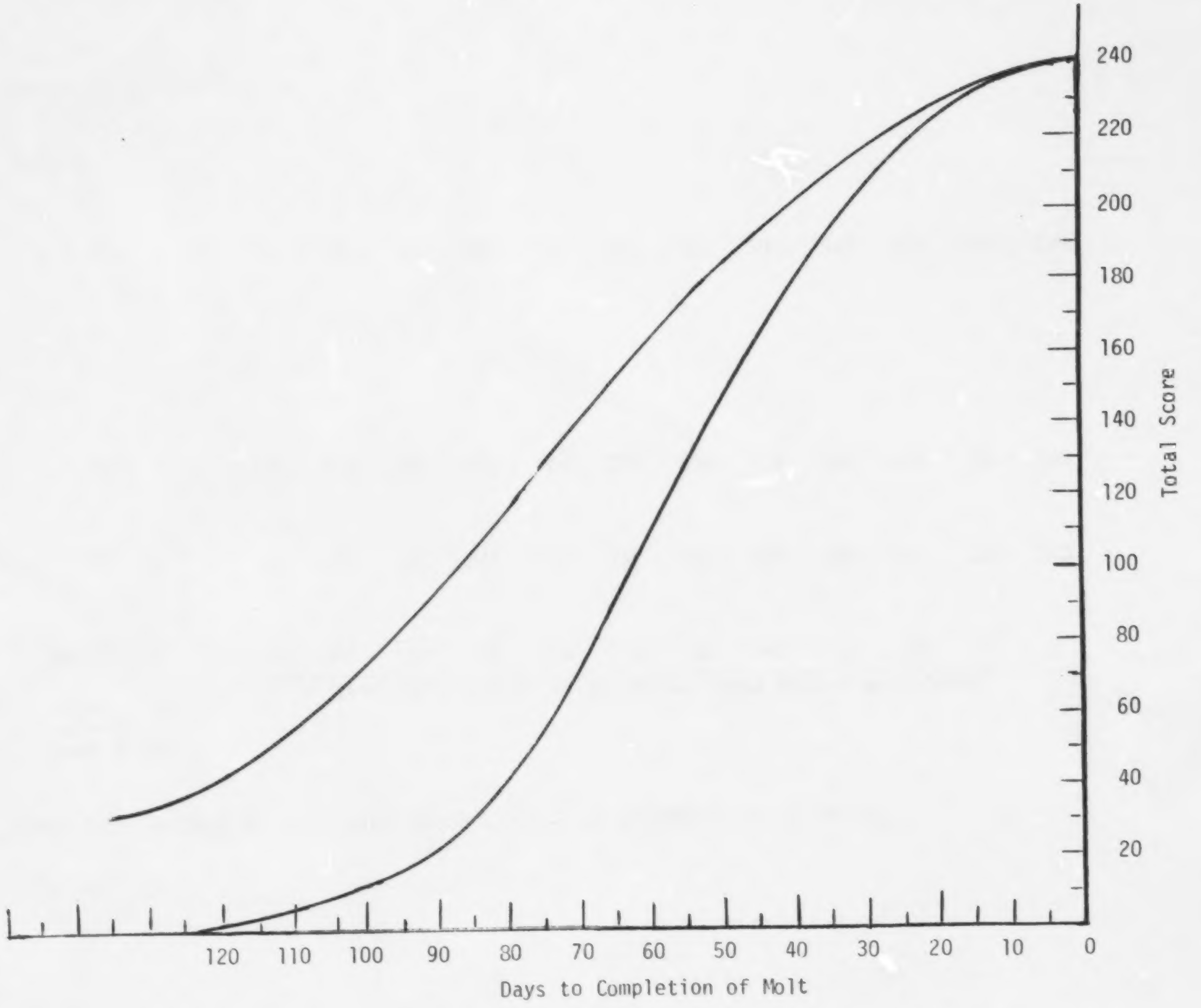


TABLE 4-24 MOLTING OF INDIVIDUAL BIRDS EXPOSED TO MICROWAVES AT 25 mW/cm^2

Bird Ident.	Time Needed for Half Score (120) to Full Molt (240)	Individual Scores at Different Times Before Molt (Days)											
		110	100	90	80	70	60	50	40	30	20	10	0
W41	92	89	108	126	142	159	175	190	204	216	227	235	240
W42	114	144	166	180	187	194	200	205	210	215	221	230	240
$\overline{X}$	103	117	137	153	165	176	188	202	207	216	224	233	240

FIGURE 4-28 MOLTING OF INDIVIDUAL BIRDS EXPOSED TO MICROWAVES AT 25 mW/cm^2

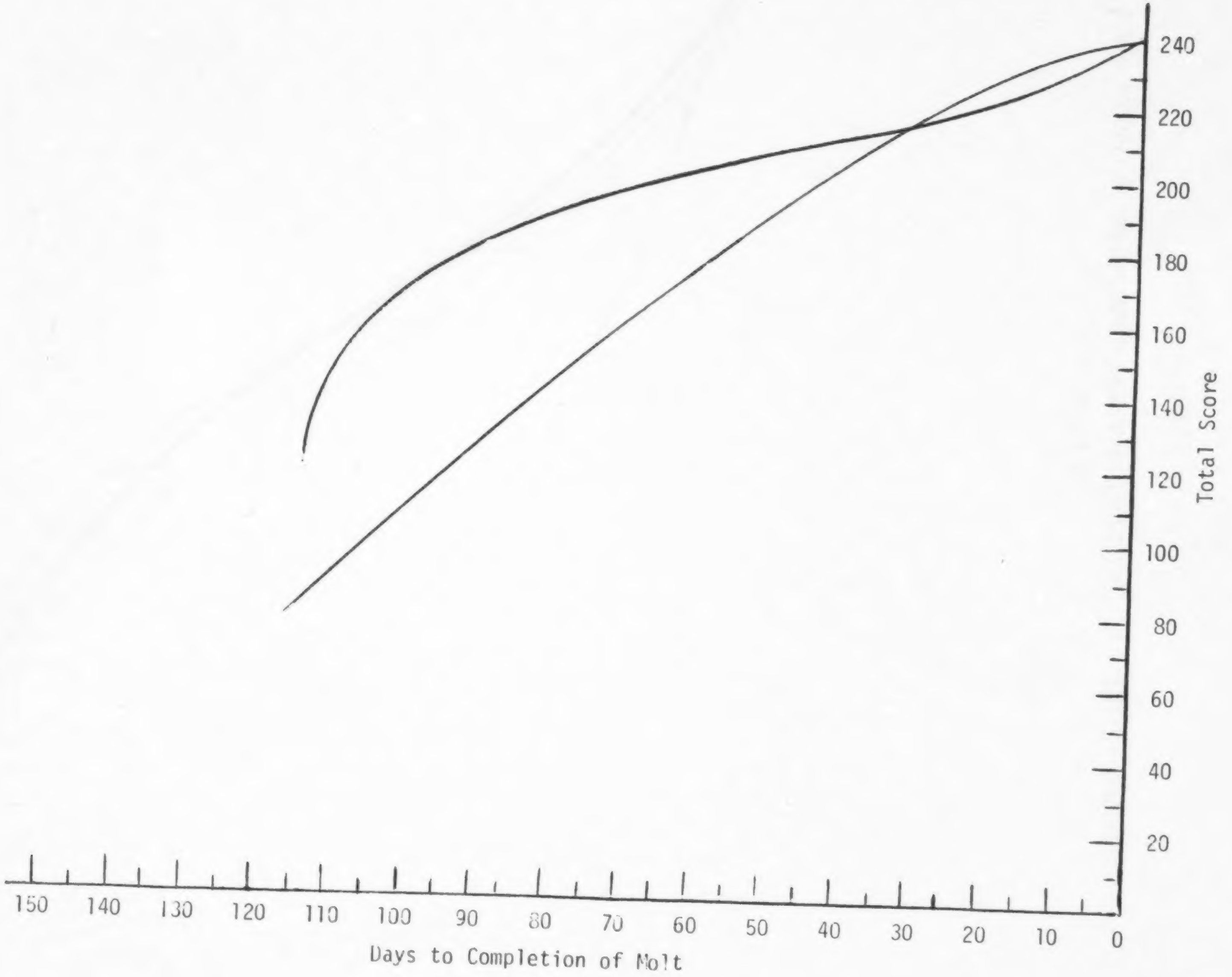
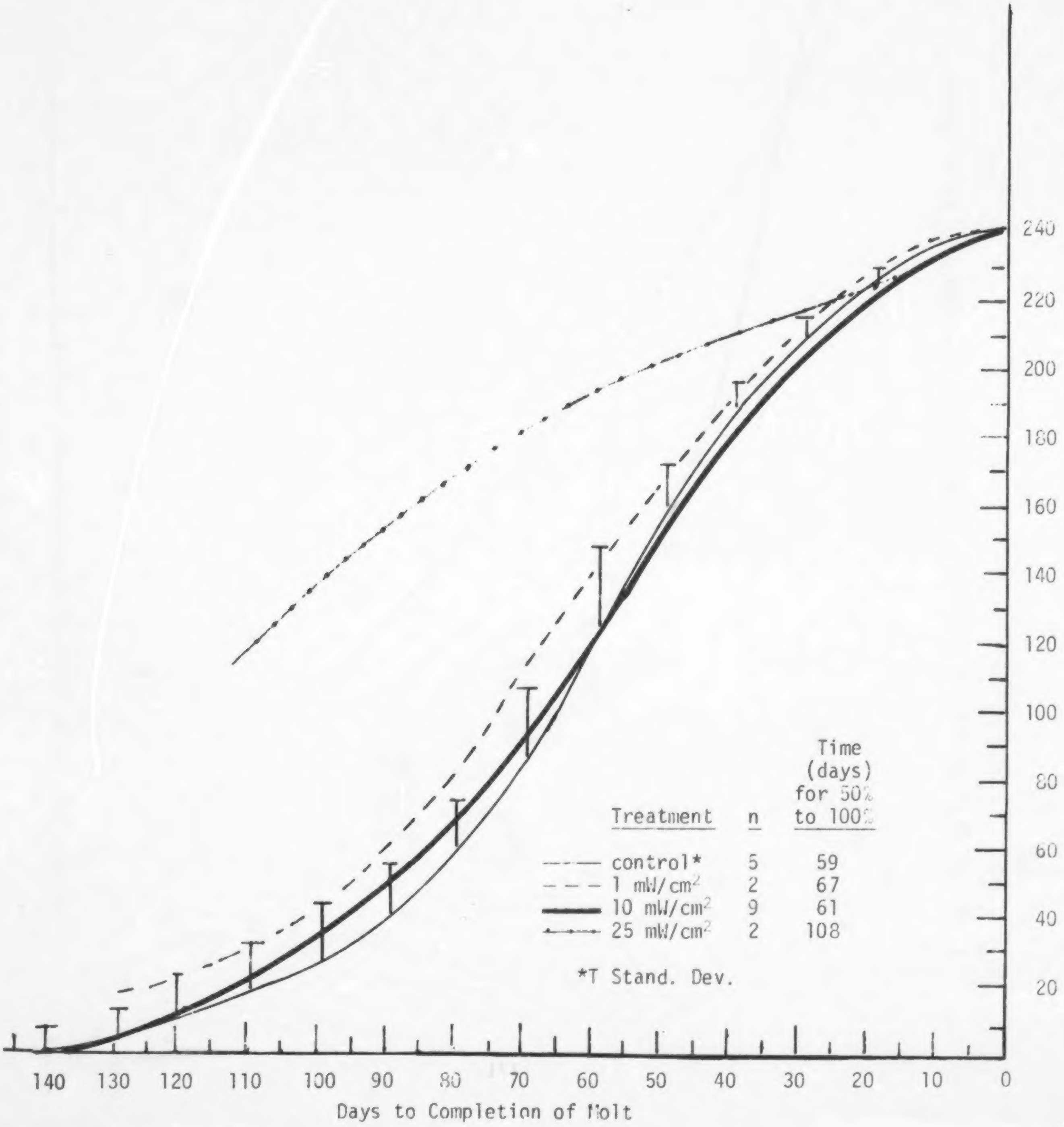


FIGURE 4-29

SUMMARY: EFFECTS OF CONTINUOUS MICROWAVE EXPOSURE ON MOLTING OF HOUSE FINCHES
110 TO 150 DAYS



the mean scores on the curve plotted for the controls. An analysis of the time required for the last half (50%) of molt revealed that the mean difference between control and 10 mW/cm^2 exposed animals using a t-test was about 2 days and it was not statistically significant ($p > 0.05$) whereas the time for the last half of molt for the 25 mW/cm^2 was estimated to be 103 to 108 days as compared to 60 days for the controls. Although both birds at 25 mW/cm^2 completed their molting process, the question as to whether the slower rate of molting was due to microwaves as the change in environment during molting (birds had already started to molt when captured) remains unresolved.

4.5.3.4 Effects of Microwaves on Length of New Feathers

In addition to using the system of scoring changes in growth of flight feathers, measurements of the length of individual feathers at the end of molt was carried out for the controls and 10 mW/cm^2 exposed birds. A decrease in length of the original feathers compared to new feathers was expected due to normal wear of the feathers since the last molt. As seen in Table 4-25 that contains the actual measurements of the original and new feathers, and Table 4-26 that contains the ratios of the length of original and new feathers of selected indicator feathers, there was no notable effect of microwaves on the length of new feathers compared to the original feathers lost during molt. When the ratios for all eight indicator feathers of the microwave treated birds were analyzed for significance by a t-test, the mean difference of the ratios (0.045) of feather length before and after molting for the controls was significantly lower ($P < 0.05$) than microwave treated animals. However, it is unlikely that this very small

TABLE 4-25 EFFECTS OF MICROWAVE IRRADIATION ON GROWTH OF FEATHERS DURING MOLTING

(a) 10 mW/cm^2 Microwave Exposure

Bird Iden.	Length of Old:New (mm)								
	P1	P4	P9	S1	S4	TT7	TL1	TL6	Mean
G9	52:49	53:52	57:56	50:46	48:42	$\overset{*a}{42}$:$\overset{*}{43}$	54:56	$\overset{a}{56}$:56	51.1:50.0
G15	49:47	$\overset{a}{52}$:52	$\overset{a}{56}$:$\overset{a}{58}$	48:47	46:45	40:41	54:53	58:58	50.4:50.1
G17	50:46	54:51	56:55	50:49	49:45	44: -	54:55	59:56	52.0:51.0
W2	52:48	53:53	55:58	48:47	46:45	$\overset{a}{43}$:44	55:55	61:60	51.6:51.3
W43	51:49	58:55	60:58	50:48	47:47	45:47	$\overset{a}{58}$:56	63:58	54.0:52.3
W44	48:46	52:52	57:54	45:47	46:45	46:47	$\overset{*}{57}$:$\overset{*}{54}$	61:54	51.5:49.9
W51	48:47	49:53	$\overset{a}{50}$:61	47:45	45:44	41:41	$\overset{a}{46}$: -	$\overset{*}{53}$:$\overset{*}{55}$	47.4:49.4
W57	53:52	54:55	$\overset{a}{53}$:58	50: 47	47:47	44:45	61:59	62:66	53.0:53.6
W58	48:48	$\overset{a}{53}$:54	$\overset{a}{50}$:59	50:50	48:47	$\overset{a}{43}$:45	$\overset{a}{53}$:57	$\overset{a}{58}$:61	50.4:52.6
Mean	50.1:48.0	53.1:53.0	54.9:57.4	48.7:47.3	46.9:45.2	43.1:44.1	54.6:55.6	59.0:58.2	51.3:51.1

(b) 0 mW/cm^2 (Controls)

Bird Iden.	P1	P4	P9	S1	S4	TT7	TL1	TL6	Mean
G2	- :49	$\overset{a}{51}$:56	$\overset{a}{54}$:56	50:48	48:48	$\overset{a}{43}$:42	- :56	- :59	49.2:51.8
G3	- :49	51:55	$\overset{a}{53}$:60	48:48	45:45	$\overset{a}{43}$:47	$\overset{a}{56}$:60	$\overset{a}{60}$:61	50.9:53.1
G5	- :48	$\overset{a}{51}$:52	$\overset{a}{55}$:58	48:48	45:46	40:44	$\overset{a}{52}$:57	57:59	49.7:51.5
G6	- :50	$\overset{a}{52}$:55	$\overset{a}{51}$:61	49:49	47:47	$\overset{a}{40}$:45	- :61	- :58	47.8:53.3
G13	- :47	52:50	58:63	48:45	45:45	$\overset{a}{42}$:42	54:55	55:58	50.6:50.6
Mean	- :48.6	51.4:53.6	54.2:59.6	48.6:47.6	46.0:46.2	41.6:44	54.0:57.8	57.3:59.0	50.44:52.05

Key: All feathers are from the bird's left side, except those marked * which are from the right. Numbers are lengths of feathers in mm (insertion to tip).

Pairs of measurements are the length of old (premolt) feather:length of new feather (after molt).

a = abraded - = absent or broken P = primary S = secondary TT = tertial TL = tail

TABLE 4-26

EFFECTS OF MICROWAVE IRRADIATION ON GROWTH OF FEATHERS DURING MOLTING

Ratio of Old to New Feathers

(a) 10 mW/cm^2 Microwave Exposure

Bird Iden.	P1	P4	P9	S1	S4	TT7	TL1	TL6	
G9	1.06	1.02	1.02	1.07	1.14	0.98	0.96	1.00	
G15	1.04	1.00	0.97	1.02	1.02	0.98	1.02	1.00	
G17	1.09	1.06	1.09	1.02	1.09	-	0.98	1.05	
W2	1.08	1.00	0.95	1.02	1.02	0.98	1.00	1.02	
W43	1.04	1.05	1.03	1.04	1.00	0.96	1.04	1.09	
W44	1.04	1.00	1.06	0.96	1.02	0.98	1.06	1.13	
W51	1.02	0.92	0.82	1.04	1.02	1.00	-	0.96	
W57	1.02	0.98	0.91	1.06	1.00	0.98	1.03	0.94	
W58	1.00	0.98	0.85	1.00	1.02	0.96	0.93	0.95	
Mean	1.043	1.001	0.956	1.029	1.037	0.978	1.002	1.016	1.008

(b) 0 mW/cm^2 (Controls)

Bird Iden.	P1	P4	P9	S1	S4	TT7	TL1	TL6	
G2	-	0.91	0.96	1.04	1.00	1.02	-	-	
G3	-	0.93	0.88	1.00	1.00	0.91	0.93	0.98	
G5	-	0.98	0.95	1.00	0.98	0.91	0.91	0.97	
G6	-	0.95	0.84	1.00	1.00	0.88	-	-	
G13	-	1.04	0.92	1.07	1.00	1.00	0.98	0.95	
Mean	-	0.962	0.91	1.022	0.996	0.944	0.94	0.967	0.963
t		1.57	1.25	0.2	1.83	0.91	2.19	1.37	
df		12	12	12	12	11	9	10	
Signif.		NS	NS	NS	NS	NS	NS	NS	

For pooled ratio's groups (a) vs. (b) signif. P <0.05 (t=3.8; 97 df) difference in feather length will influence flight and survival of the birds and, therefore, should not be considered of biological consequence.

4.5.4 Gross and Microscopic Examination of House Finches Irradiated Continuously

To determine whether continuous exposure to microwave irradiation of birds to 10 and 20 mW/cm^2 results in organ damage, twelve exposed and six control birds from the molt experiment were examined grossly initially at Arthur D. Little and then sent to Dr. S. W. Nielsen, DVM, Ph.D. at the University of Connecticut for necropsy and histopathologic examination (see Appendix A4.5-2). An examination of the treated and control birds revealed no observable effects in overt behavior or in selected visceral and somatic reflexes due to microwave irradiation. Each bird was observed for changes in muscle tone, righting reflex, vestibular function, pupillary, (light) reflex, and corneal and lid pain reflexes. The cornea and lense were also examined with an ophthalmoscope for evidence of opacity and the retina damage, e.g., changes in color.

A necropsy was performed first on the six birds irradiated with microwave at a level of 25 mW/cm^2 along with the six control birds. In the event pathology was observed on either gross or histopathology, the intent was to necropsy the six birds exposed to the 10 mW/cm^2. The necropsy was carried out with special emphasis placed on tissues that reportedly are most sensitive to microwaves (i.e., eye, bone marrow, and blood, gonads, brain, thymus and adrenals). Since no gross or histopathology was found at the 25 mW/cm^2 level, the six birds at lower dose or 10 mW/cm^2 were not necropsied.

A copy of the pathology report submitted by Dr. Nielsen is also provided.

In summary, these results fail to show any gross or microscopic pathology attributable to microwave irradiation of birds as might be encountered at a rectenna site at levels proposed for SPS system.

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4.6 FORAGING BEHAVIOR (TIME BUDGET) EXPERIMENTS

4.6.1 Introduction

The following experiments were designed to determine the effects of microwave exposure on the ability of birds to find food and make the necessary manipulations for its ingestion.

4.6.2 General Procedure

White-throated Sparrows (Zonotrichia albicollis) were exposed to microwaves and various parameters of their foraging behavior were measured. Microwave exposures were of three distinct durations: (1) Acute Multiple (Brief), (2) Seven-Day Continuous, and (3) Four-Week Continuous. Continuous is defined as exposures lasting 24 hours a day except for brief intervals when exposures were halted for feeding and cleaning of cages. Acute Multiple (brief) exposures were conducted at power densities of 0.0, 0.1, 10.0 and 25.0 mW/cm^2 for 2, 20, or 200 minutes. Seven-Day exposures were conducted at power densities of 0.0, 0.1, 1.0, 10.0, and 25.0 mW/cm^2 and Four-Week exposures were conducted at power densities of 0.0 and 25.0 mW/cm^2. Details of exposure regimens will be described later.

Measurements of foraging behavior were made as follows. Experimental and sham control birds were randomly selected (between 0900 and 1600 hours), weighed, and deprived of food for one to three hours before treatment. Each bird was then released into one side of a specially designed microwave transparent cage (0.9 x 0.9 x 0.44 m) (Figure 4-30). Cages were divided in half by a visually opaque wall. One half of each cage served as a foraging arena. Each bird was allowed access from one arena to the other through a

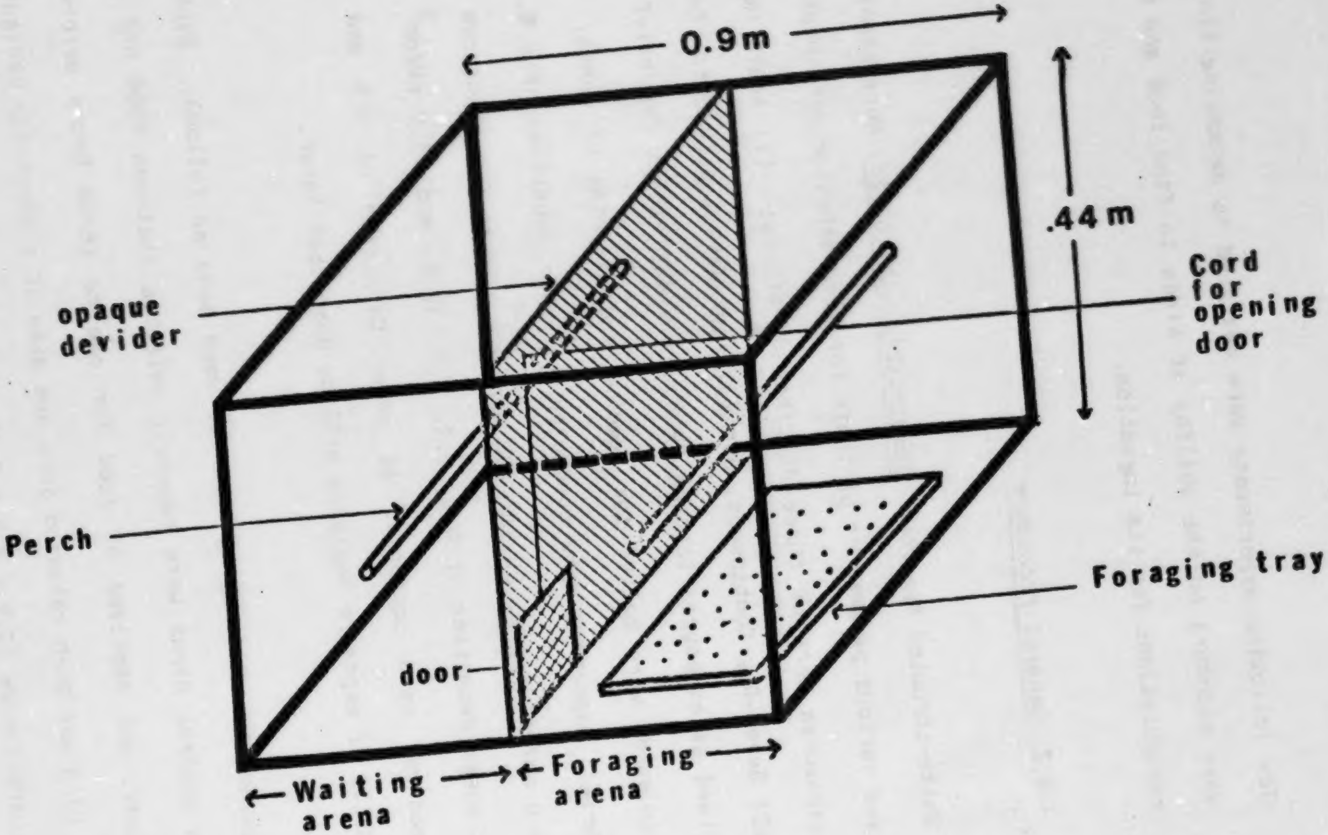
0.9m
.44 m
opaque devider
Cord for opening door
Perch
Foraging tray
door
← Waiting arena →
← Foraging arena →

Figure 4-30

Microwave Transparent Observation Cage Used for Foraging (time budget) Studies of White-throated Sparrows in Response to Acute Multiple (brief), Seven-day Continuous and Four Week Continuous Exposure to Microwaves.

manually operated door. Each half cage allowed independent placement and removal of foraging trays (ca. 36 x 61 cm). Foraging trays were constructed of Ensolite^R boards with 50 cylindrical cavities, each 8 mm in diameter and 13 mm deep. The cavities were arranged in a uniform grid with distances between the center of the cavities of 7.5 and 5.5 cm for horizontal and vertical rows, respectively.

A foraging tray was prepared by randomly placing one mealworm (Tenebrio sp.) in 25 of the 50 available cavities. Mealworms had been treated previously with hot water to immobilize them. An opaque adhesive label (19 x 12.5 mm) was placed over each of the 50 cavities to conceal the well. The tray was placed into the foraging arena 15 minutes after the bird was introduced to the waiting arena (Figure 4-30). The door in the opaque divider was manually opened permitting the bird to enter the foraging arena. Search time, handling time, and nonforaging time were recorded at two-second intervals for 15 minutes using a Rustrak® event recorder. Profitability was defined as number of prey caught per second of foraging (searching + handling time), and search efficiency was defined as number of prey captured per second of search time.

Eighteen White-throated Sparrows collected in May and October, 1980 were used in these experiments. Between treatments, all animals were housed in cages (43 x 33 x 59 cm) framed of metal or wood, and enclosed with plastic hardware cloth. The birds were fed a diet consisting of wild bird seed, alfalfa sprouts, broccoli, cabbage, hard-boiled eggs, egg shells, and mealworm larvae. A vitamin supplement was administered either in water or as a dry powder added to their food. Food was provided *ad libitum* except during the foraging experimental regimen. During the study from August to December the birds were maintained on a natural light cycle. Light cycle from January to March was increased weekly by 15 minutes until a 12:12 light/dark cycle was achieved. This change was required for other experiments to be carried out in the same facility.

4.6.2.1 Acute Multiple (Brief) Exposures

The design of the Acute Multiple (Brief) exposure regimen is presented in Table 4-27. Each of the three White-throated Sparrows (Birds #2, 4, and 6) was exposed to microwaves for 2, 20 or 200 minutes at power densities of 0.1, 10.0 and 25.0 mW/cm^2. The birds were tested sequentially as follows: three sham treatments (week 1), three microwave treatments (week 2), three sham treatments (week 3), and microwave treatments (week 4) These are hereafter referred to as week 1, 2, 3, and 4, respectively. The sequence resulted in a total of six observations for the sham controls and six observations for the microwave treatment. Three additional birds were included as unexposed parallel (sham) controls (Birds #1, 3, and 5), one for each of the three exposure durations. The high degree of individual behavioral variability observed during training made it necessary to use an experimental design in which each microwave treated bird also received sham treatment prior to microwave treatment in order to use each animal as its own control.

Birds were randomly assigned a treatment duration of 2, 20 or 200 minutes and, throughout the experiment, always received treatments of the same time duration.

Table 4-27

Experimental Design for Acute Multiple (Brief) Microwave Exposure Experiments on Foraging Behavior (time budget) of White-throated Sparrows. This regimen applies to each power Density (0.1, 10.0, and 25.0 mW/sq.cm.)

			Regimen*							
Exp. No.	Treatment Group	Bird No.	Exposure Time (min)	Number of Days per Week	Number of Weeks	Total No. of Trials	Treatment Sequence by wk (1)	(2)	(3)	(4)
1	E	#6	200	3	4	12	S	E	S	E
	S	#5(a)	200	3	4	12	S	S	S	S
2	E	#4	20	3	4	12	S	E	S	E
	S	#3(a)	20	3	4	12	S	S	S	S
3	E	#2	2	3	4	12	S	E	S	E
	S	#1(a)	2	3	4	12	S	S	S	S

E = Exposure - birds were placed in chambers and irradiated prior to being tested.

S = Sham - birds were placed in identical chambers but not irradiated prior to being tested.

* For each exposure period and during sham treatments, a 15 minute waiting period was followed by a 15-minute foraging period.

(a) parallel sham controls.

After being deprived of food and exposed to microwaves (in a microwave irradiation chamber Figure 4-32) each bird was removed and placed in an observation chamber (Figure 4-31). This chamber (2.4 x 1.2 x 1.2 m) was constructed of wood and cardboard sheets and located two meters from microwave and control chambers. Birds were visually isolated from distractions resulting from other experiments being conducted in the same facility. Temperature measurements were made inside and in the immediate area outside the test chamber. Birds were allowed to accommodate to the cage within the test chamber for 15 minutes and then observations were made during the 15 minute foraging period. Experiments at power density 0.1 mW/cm^2 commenced August 6, 1980, whereas experiments at power densities of 10.0 and 25.0 mW/cm^2 commenced on September 4, 1980 and November 15, 1980, respectively.

4.6.2.2 Seven-Day Microwave Exposures

Four White-throated Sparrows were exposed continuously for seven days at one of four power densities (0.1, 1.0, 10.0, and 25.0 mW/cm^2). Two additional birds served as parallel sham controls (0.0 mW/cm^2). The duration of each experiment was three weeks; seven days pre-exposure, seven days exposure, and seven days post-exposure. Each bird was housed in a replicate of the observation cage (Figure 4-30). Seed dispensers, water tubes, and vegetable cups were placed in the "waiting arena" side of the cage. These cages were then placed in control chambers during pre-exposure periods, in exposure chambers during exposure periods and in control chambers during post-exposure periods (Figure 4-32). Parallel control sham birds (0.0 mW/cm^2) were housed in control chambers during all three

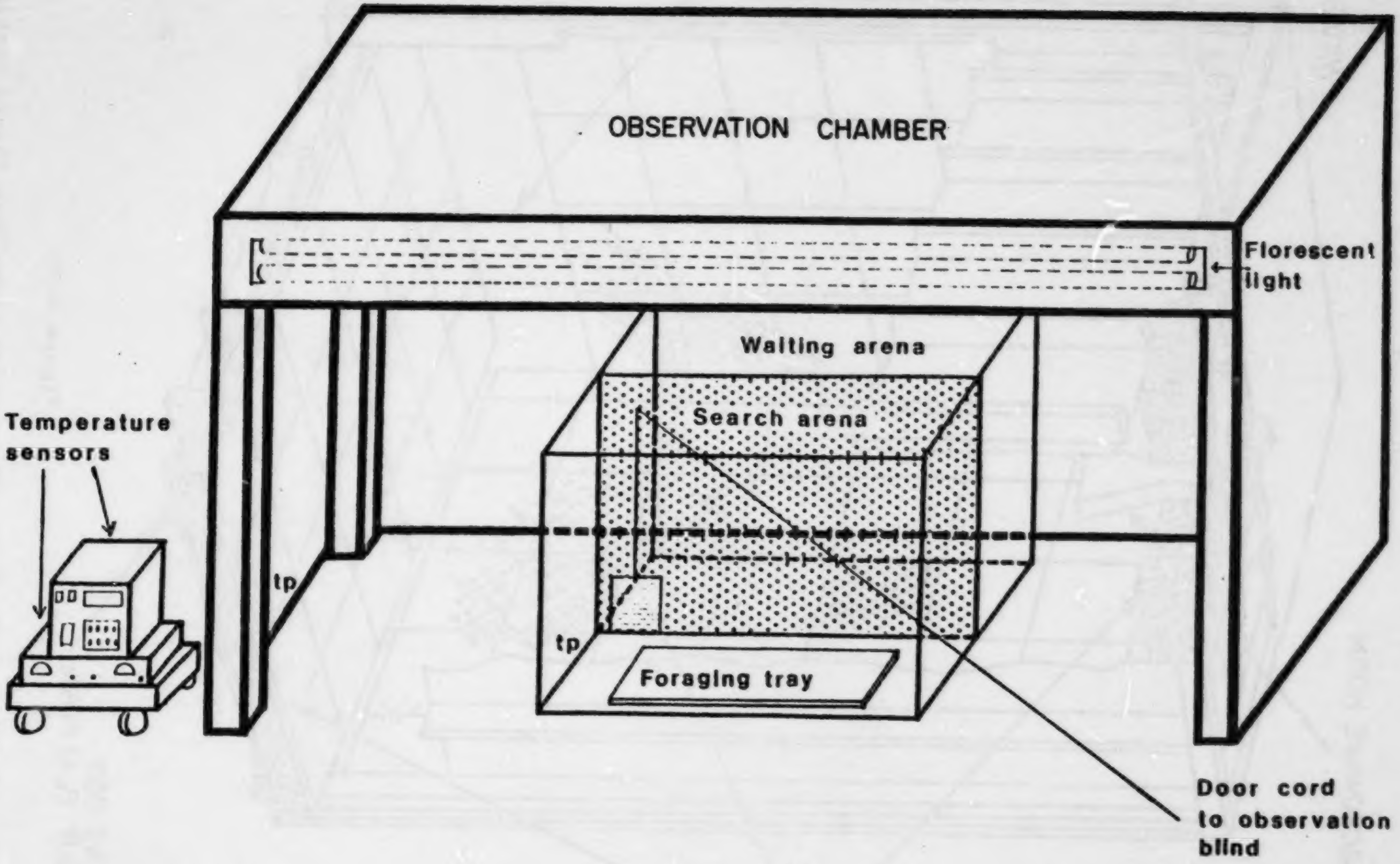
OBSERVATION CHAMBER
Florescent light
Waiting arena
Search arena
Temperature sensors
tp
tp
Foraging tray
Door cord to observation blind

Figure 4-31

Chamber Where Observations Were Made on the Foraging Behavior (time budget) of White-throated Sparrows After Acute Multiple (Brief) Exposure to Microwaves; tp refers to location of temperature probes for recording ambient temperature inside and outside test chamber.

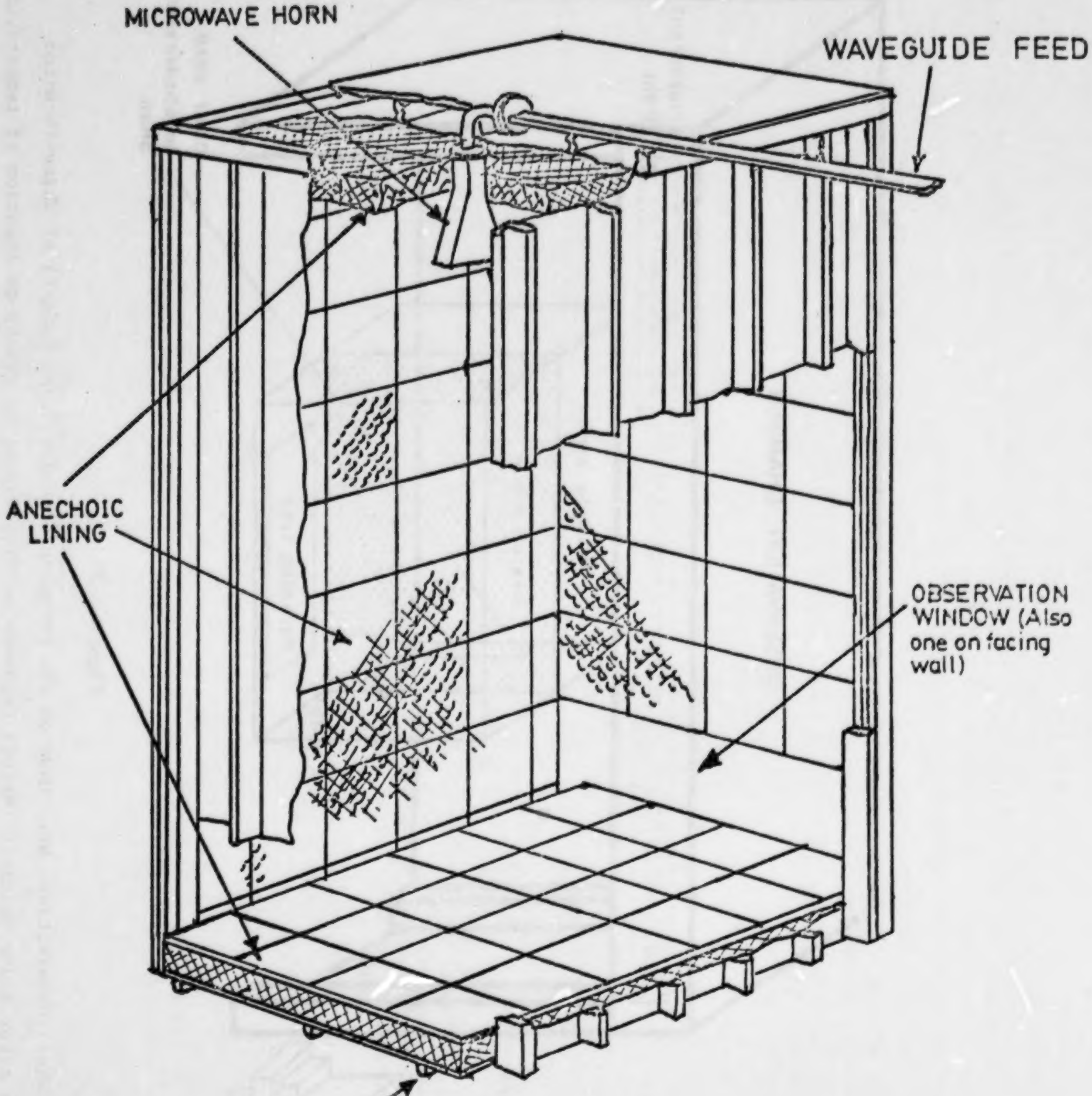
MICROWAVE HORN
WAVEGUIDE FEED
ANECHOIC LINING
OBSERVATION WINDOW (Also one on facing wall)
CASTERS FOR ROLL-OUT PLATFORM

Figure 4-32

Microwave Irradiation Chamber. Observation Cages Were Placed Within Each Chamber (0.1, 1.0, 10.0, and 25.0 mW/cm^2) for Seven Day Chronic Exposure. Chambers designed for 10.0 and 25.0 mW/cm^2 exposure required anechoic cones rather than blocks for roll-out platforms to reduce heat ~~build~~-up. Cages in these chambers were hung from the chamber ceiling or placed on microwave transparent stands.

periods. In order to minimize behavioral differences between sham and microwave treated birds, the positions for the cages of sham birds were changed whenever the cage positions of treated birds were changed.

Microwave treated birds were irradiated for seven days, 24 hours per day except for brief periods during each day when maintenance activities were performed or when being prepared for observations of foraging behavior. Birds were deprived of food in random order, then allowed to enter the search arena and forage for 15 minutes while being irradiated. Observations were made three times per week during the experiment. Ambient temperature measurements were taken both inside and outside of the exposure and control chambers. This experiment was replicated once, resulting in six trials per exposure period.

4.6.2.3 Four-Week Microwave Exposure

This experiment was designed to test the effects of Four-Week continuous microwave exposures on foraging behavior of White-throated Sparrows which were used in either the acute or seven-day exposure experiments described above. Only birds which exhibited no residual effects of previous microwave exposure (as indicated by normal foraging behavior after termination of microwave treatments) were used in the experiment. Over a four-week period, six birds were exposed at a power density of 25.0 mW/cm^2 and five parallel (sham) control birds at 0.0 mW/cm^2. Sham control birds had never been exposed to microwaves. The duration of the experiment was eight weeks with a two-week pre-exposure, four-week exposure, and a two-week post-exposure period. Observations on foraging behavior were made once per week. Birds were exposed 24 hours per day except for short periods when maintenance duties were performed or when observations of foraging behavior were made. Due to space limitations within both control and exposure chambers, more than one bird was housed per cage. The cage which held parallel (sham) control birds housed three birds in one side of the cage and two birds in the other half. The cage used for the exposure treatment held three birds to a side. Birds were then deprived of food, then removed in random order, and placed in the waiting arena of the observation cage within the test chamber (Figure 4-31), and then allowed to accommodate for 15 minutes before the 15-minute foraging period. The same measures of foraging behavior, search time, handling time and nonforaging time were recorded as during the acute and seven-day experiments. One replicate of this experiment was carried out. Ambient temperature measurements were taken both inside and outside of the exposure and control chambers.

4.6.3 Results

4.6.3.1 Results Acute Multiple (Brief) Exposures

Three White-throated Sparrows were exposed to microwaves at power densities of 0.1, 10.0 and 25.0 mW/cm^2 during 3 sequential 4 week periods. One bird was exposed to each of the three power densities for two minutes, another for 20 minutes, and a third for 200 minutes. The data are provided for microwave exposure, number of prey eaten, search time, handling time, profitability, and search efficiency in Appendices A4.6-1 to A4.6-5.

Data used in comparing observations between Week-One (sham treatment for all birds) and Week Two (sham treatment for birds 1, 3, and 5 and exposure treatment for birds 2, 4, and 6) for each bird was subjected to a Wilcoxon two-sample test. This procedure was repeated in order to compare weeks three and four for each bird. The results of these analyses are summarized in Table 4-28.

At a power density of 0.1 mW/cm^2 significant differences in foraging efficiency were observed for all birds except for bird 6. The majority of these differences indicate greater foraging success during week three (sham treatment for all birds) than during week four (sham treatment for birds 1, 3, and 5; microwave treatment for birds 2, 4 and 6). Significant differences in sham as well as microwave exposed birds indicates random variation and/or that the influencing factors were not related to microwave exposure. The behavior of birds seemed to vary with certain environmental factors such as temperature and relative humidity. During August, when the experiment was conducted at power density 0.1 mW/cm^2, temperature and relative humidity varied substantially (Tables 4-29 and 4-30). The temperature during week number three was considerably lower and relative humidity significantly higher than during week four (Wilcoxon two-sample test: temperature $p<0.08$, relative humidity $p<0.05$). The greater success in foraging during week number three may have been due to the temperature and relative humidity differences between weeks three and four.

A Spearman correlation analysis (two-tailed test) comparing temperature and humidity to each foraging variable resulted in a significant negative correlation between temperature and number of prey eaten ($n = 72$, $p<0.008$);

Table 4-28

Summary of Results of Wilcoxon "Two-Sample" Test Between Weeks 1 and 2 and Weeks 3 and 4 for Foraging Behavior After Acute Multiple (Brief) Exposure at 0.1, 10.0, and 25.0 mW/cm^2

Bird No.	Exposure time (min)	Treatment group	Variable	P values					
				0.1 mW/cm		10.0 mW/cm		25.0 mW/cm	
				Wk. 1 vs. 2	Wk. 3 vs. 4	Wk. 1 vs. 2	Wk. 3 vs. 4	Wk. 1 vs. 2	Wk. 3 vs. 4
1	2	S	No. of Prey	- -	- -	- -	- -	.03*	- -
			Search T.	- -	- -	- -	- -	.03*	.03*
			Handling T.	- -	- -	- -	- -	- -	- -
			Profit.	- -	.03*	.03*	- -	- -	- -
			Search Eff.	- -	- -	.03*	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
2	2	E	No. of prey	- -	.05*	- -	- -	- -	- -
			Search T.	- -	- -	- -	- -	- -	- -
			Handling T.	- -	.03*	- -	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	.03*
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
3	20	S	No. of Prey	- -	.03*	- -	- -	- -	.03*
			Search T.	- -	- -	- -	- -	- -	- -
			Handling T.	- -	.05*	- -	- -	- -	- -
			Profit.	- -	.03*	- -	- -	- -	- -
			Search Eff.	- -	.03#	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	.03*	- -
4	20	E	No. of Prey	- -	.05*	- -	- -	- -	- -
			Search T.	- -	- -	- -	- -	- -	- -
			Handling T.	- -	.03*	- -	- -	- -	- -
			Profit.	.03*	.03#	- -	- -	- -	- -
			Search Eff.	.03*	.03*	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
5	200	S	No. of Prey	- -	.03*	- -	- -	- -	- -
			Search T.	- -	- -	- -	- -	- -	- -
			Handling T.	- -	- -	- -	- -	- -	- -
			Profit.	- -	.03*	- -	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T	- -	- -	.03*	- -	- -	- -
6	200	E	No. of Prey	- -	- -	- -	- -	- -	- -
			Search T.	- -	- -	- -	- -	- -	.03*
			Handling T.	- -	- -	.05*	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -

E = Exposure in which birds were placed in microwave chambers and irradiated prior to being tested during week 2 and 4

S = Sham treatment in which birds were placed in identical chambers but not irradiated prior to being tested.

* = Sham treatment means significantly greater than Exposure treatment means.

= Exposure treatment means significantly greater than Sham treatment means.

- = No significant differences.

Table 4-29

Mean Ambient Room Temperature (Standard Deviation) by Week for Acute Multiple (Brief) Exposure to Microwaves at Power Density 0.1 mW/cm^2.

Bird No.	Exposure Time (minutes)	Mean Temperature (Ta)°C*			
		Week 1	Week 2	Week 3	Week 4
1	2	29.8 (2.5)	23.5 (1.2)	21.7 (0.6)	27.2 (1.1)
2	2	29.1 (2.2)	23.9 (2.4)	21.1 (1.1)	27.6 (0.8)
3	20	31.1 (1.4)	23.3 (0.6)	21.9 (0.9)	26.5 (0.8)
4	20	29.8 (1.4)	24.1 (2.2)	21.1 (1.1)	27.6 (1.2)
5	200	30.9 (1.4)	24.4 (2.2)	21.7 (0.6)	27.6 (0.6)
6	200	31.5 (1.4)	23.7 (1.7)	21.7 (0.6)	27.6 (0.8)

* Means are based on three measurements of temperature, one preceding each tri-weekly observation of foraging behavior.

Table 4-30

Mean Relative Humidity (Standard Deviation) for Acute Multiple (Brief) Exposures to Microwaves at Power Density 0.1 mW/cm^2

Bird No.	Exposure Time (minutes)	Relative Humidity[(a)] Week 1	Week 2	Week 3	Week 4
1	2	67.5 (2.1)	61.3 (4.0)	86.7 (5.0)	67.3 (7.1)
2	2	68.0 (2.8)	61.3 (4.0)	90.3 (1.5)	66.0 (11.8)
3	20	67.0 (1.4)	63.7 (0.1)	86.7 (5.0)	73.7 (5.8)
4	20	66.0 (1.4)	63.7 (4.0)	90.3 (1.5)	67.3 (12.3)
5	200	65.5 (2.1)	66.0 (0.6)	89.0 (3.0)	65.7 (10.6)
6	200	66.5 (0.7)	66.0 (3.6)	86.7 (5.0)	65.0 (9.0)

(a) Means are based on three measurements of relative humidity preceding experiment.

temperature and profitability (n = 72, $p<0.04$); and a significant positive correlation of humidity to the number of prey eaten (n = 66, $p<0.04$) and humidity and profitability (n = 66, $p<0.02$). These findings are consistent with data presented in Table 4-28. Four of the five birds with significant differences in foraging behaviors consumed a significantly higher number of prey during Week Three, when it was cool and humid, than during week four when it was hot and less humid. This may well explain the higher values for search efficiency observed during week number four for birds 3 and 4 (since energy expenditure is minimized when ambient temperature is high, we would expect greater search efficiency in week four than in week three). The same reasoning may explain higher values for profitability for bird 4 during week one.

The data also were analyzed by comparing observations between week number one (sham treatment for all birds) and week three (sham treatment for all birds) for each bird using a Wilcoxon two-sample test. This procedure was repeated comparing week number two (sham treatment for birds 1, 3, and 5 and exposure treatment for birds 2, 4, and 6) and week number four (sham treatment for birds 1, 3, and 5 and exposure treatment for birds 2, 4, and 6). The results of these analyses are summarized in Table 4-31.

Results of experiments at power density 0.1 mW/cm^2 are interesting because all of the birds exposed to microwaves showed significant differences in foraging efficiencies between the first week exposure (week 2) and the second week of exposure (week 4). Temperature was not significantly different between week two and week four (Table 4-29). There was a significant difference in temperature between week one and week three ($p<0.03$),

Table 4-31

Summary of Results of Wilcoxon "Two-Sample" Test Between Weeks 1 and 3 and Weeks 2 and 4 for Foraging Behavior After Acute Multiple (Brief) Exposure at a Power Density of 0.1, 10.0, and 25.0 mW/cm^2

				p values					
				0.1 mW/cm		10.0 mW/cm		25.0 mW/cm	
Bird No.	Exposure time (min)	Exposure Cond.	Variable	Wk. 1 vs. 3	Wk. 2 vs. 4	Wk. 1 vs. 3	Wk. 2 vs. 4	Wk. 1 vs. 3	Wk. 2 vs. 4
1	2	S	No. of Prey	- -	- -	.03 (1)	- -	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	- -	- -	- -	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	- -
			Search Eff.	- -	- -	.03 (1)	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	.03 (3)	.03 (4)
2	2	E	No. of Prey	- -	.03 (2)	.03 (1)	.03 (2)	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	- -	.03 (2)	- -	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
3	20	S	No. of Prey	- -	- -	.03 (1)	- -	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	- -	- -	.03 (1)	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
4	20	E	No. of Prey	- -	.03 (2)	- -	- -	- -	- -
			Search Time	- -	- -	- -	.03 (2)	- -	- -
			Handling T.	- -	.03 (2)	- -	- -	- -	- -
			Profit.	- -	.03 (2)	- -	- -	- -	- -
			Search Eff.	- -	.03 (2)	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
5	200	S	No. of Prey	- -	.03 (2)	- -	.05 (2)	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	- -	.03 (2)	- -	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
6	200	E	No. of Prey	- -	- -	.03 (1)	- -	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	.03 (1)	.03 (2)	.03 (1)	- -	- -	- -
			Profit.	- -	.03 (2)	- -	- -	- -	- -
			Search Eff.	- -	.03 (2)	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -

For abbreviations see Table 4-28

(1) = Week 1 means significantly greater Week 3 mean.
(2) = Week 2 means significantly greater Week 4 mean.
(3) = Week 3 means significantly greater Week 1 mean.
(4) = Week 4 means significantly greater Week 2 mean.

but only handling time differed significantly ($p<0.03$) for bird 6. This could indicate a nonthermal microwave effect on foraging efficiency at a power density of 0.1 mW/cm^2. However, analyses at higher power densities (Table 4-31) of 10.0 and 25.0 mW/cm^2 do not support this conclusion.

At a power density of 10.0 mW/cm^2 a significantly higher number of prey were eaten ($p<0.05$) during week number one compared to week number three. These weeks represented sham treatment for all birds and therefore could not be indicative of a microwave effect. These birds however, were observed at a time when they would normally be in seasonal preparation for migration (early September and October) (Figure 4-33). Before migrating, a bird must be ready to meet the energy requirements for prolonged flight. It accomplishes this by eating amounts of food in excess of its daily needs and thereby storing energy in the form of subcutaneous fat (Pettingill, 1970). Number of prey eaten would also affect handling time, hence the significant differences shown in handling time between week number one and week number three. Handling time was greater during week number one than during week three (Appendix A4.6-3). This reasoning could also explain differences in number of prey and search time between weeks two and four. At a power density of 25.0 mW/cm^2 significant differences in foraging efficiency were shown only in sham-treated birds; therefore, microwave exposure was not the causal factor. Random variation may account for the differences observed.

Finally, the data were analyzed by comparing Week One (sham treatment for all birds) and Week Four (sham treatment for birds 1, 3, and 5 and exposure treatment for birds 2, 4, and 6) for each bird using a Wilcoxon two-sample

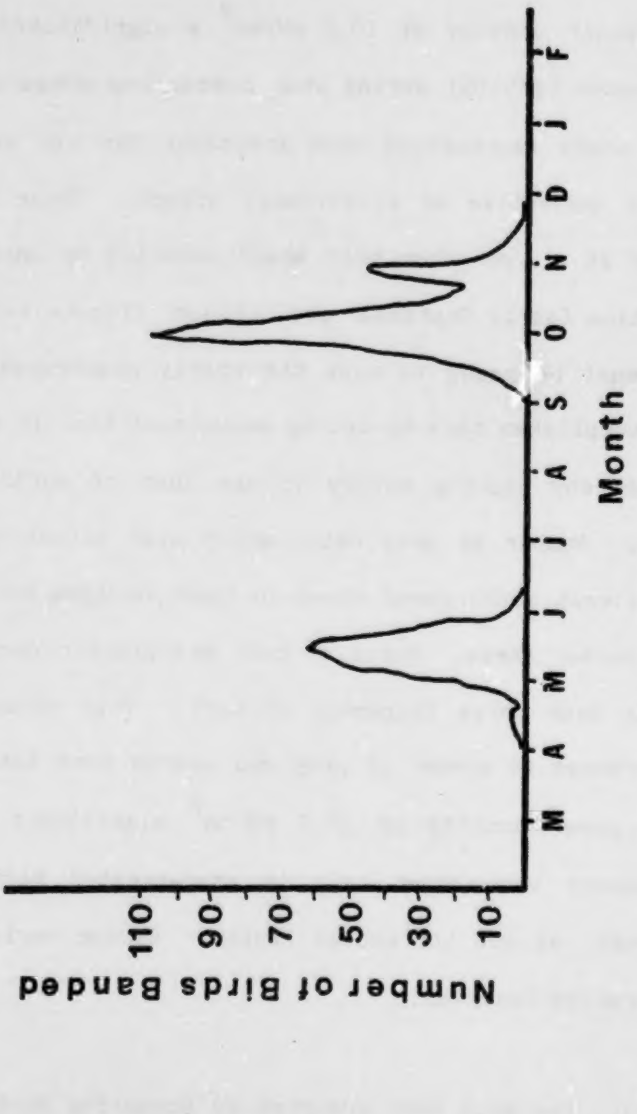

Figure 4-33

White-throated Sparrows (Zonotrichia albicollis) Banded During Migration at Manomet Bird Observatory in 1978.

test. This procedure was repeated comparing week two and week three. The results of these analyses are summarized in Table 4-32.

Foraging efficiency was affected in both sham and microwave treated birds at a power density of 0.1 mW/cm^2 and causal factors are unclear but may be attributed to individual animal variation enhanced by the increased time span between observations made during week one and week four. This reasoning is upheld by the small amount of significant differences found between weeks two and three. This trend continues at higher power densities of 10.0 and 25.0 mW/cm^2. Analysis of data for power density 10.0 mW/cm^2 gives added support that seasonal preparation for migration generally enhanced foraging efficiency during the early weeks of observations at this power density. These analyses do not indicate any effect on foraging behavior due to microwave exposure at power densities of 0.1, 10.0 or 25.0 mW/cm^2.

A Wilcoxon paired comparison test was conducted on paired observations for each measurement of foraging behavior for each week between sham and exposed birds for each power density and time exposure (Bird #1 compared to #2, #3 to #4 and #5 to #6). No significant differences were found for any of the measured behaviors.

4.6.3.2 Results Seven-Day Microwave Exposures

We exposed four different White-throated Sparrows for seven days to one of four power densities (0.1, 1.0, 10.0 and 25.0 mW/cm^2). In addition, two birds served as sham parallel controls (0.0 mW/cm^2). This experiment was

Table 4-32

Summary of Results of Wilcoxon "Two-Sample" Test Between Weeks 1 and 4 and Weeks 2 and 4 for Foraging Behavior After Acute Multiple (Brief) Exposure at 0.1, 10.0, and 25.0 mW/cm^2

Bird No.	Exposure time (min)	Exposure Cond.	Variable	p values					
				0.1 mW/cm		10.0 mW/cm		25.0 mW/cm	
				Wk. 1 vs. 4	Wk. 2 vs. 3	Wk. 1 vs. 4	Wk. 2 vs. 3	Wk. 1 vs. 4	Wk. 2 vs. 3
1	2	S	No. of Prey	- -	- -	.03*	- -	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	- -	- -	.03*	- -	- -	- -
			Profit.	- -	- -	.03*	- -	- -	- -
			Search Eff.	- -	- -	.03*	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	.03#
2	2	S	No. of Prey	- -	- -	.03*	- -	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	- -	.03#	- -	- -	- -	- -
			Profit.	- -	- -	.03*	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
3	20	S	No. of Prey	.05*	- -	- -	.03#	- -	- -
			Search Time	.05#	- -	- -	- -	- -	- -
			Handling T.	- -	- -	- -	.03#	- -	- -
			Profit.	.03*	- -	- -	- -	- -	- -
			Search Eff.	.03	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	.03*	- -
4	20	E	No. of Prey	- -	- -	- -	- -	- -	- -
			Search Time	- -	- -	- -	- -	- -	- -
			Handling T.	.05*	- -	- -	- -	- -	.05#
			Profit.	.03*	- -	- -	- -	- -	- -
			Search Eff.	.03*	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
5	200	S	No. of Prey	.05*	- -	- -	.03#	- -	.03#
			Search Time	- -	- -	- -	.03#	- -	- -
			Handling T.	- -	- -	- -	- -	- -	- -
			Profit.	- -	- -	- -	- -	- -	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -
6	200	E	No. of Prey	- -	- -	.03*	- -	.05*	- -
			Search Time	- -	.05*	- -	- -	- -	- -
			Handling Time	- -	.03#	.03*	.03#	- -	- -
			Profit.	- -	- -	.03*	- -	.03*	- -
			Search Eff.	- -	- -	- -	- -	- -	- -
			Nonforag. T.	- -	- -	- -	- -	- -	- -

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* = Sham treatment means significantly greater than Exposure treatment means.
# = Exposure treatment means significantly greater than Sham treatment means.

replicated once using six naive birds and the data pooled by power density (Table 4-33). For each power density an analysis of variance (ANOVA) was computed to determine if there were any significant differences in foraging behavior among pre-exposure, exposure and post-exposure periods. Comparisons were made among pre-exposure, exposure and post-exposure foraging behavior measurements by Duncan's Multiple Range test. Profitability differed significantly ($p<0.05$) among periods for parallel sham control (0.0 mW/cm^2) birds. Chamber temperatures varied significantly among periods for birds exposed to power densities of 25.0 mW/cm^2 ($p<0.05$). Mean profitability was significantly lower ($p<0.05$) during the pre-exposure period for parallel sham control (0.0 mW/cm^2) birds (Table 4-34). Chamber temperatures were significantly higher ($p<0.05$) during microwave exposure at 10.0 and 25.0 mW/cm^2 (Appendices A4.6-9 and A4.6-10) than during pre-exposure or post-exposure periods, but higher chamber temperatures had no significant effect on foraging behavior (Table 4-33).

4.6.3.3 Four Week Exposure Results

We exposed six White-throated Sparrows at a power density of 25.0 mW/cm^2. Five additional birds served as parallel (sham) controls. A replicate of this experiment was conducted with four birds exposed to microwaves at a power density of 25.0 mW/cm^2 and two birds serving as parallel sham controls. The data for the 10 microwave exposed and seven control birds were pooled (Table 4-34). An analysis of variance (ANOVA) was conducted on these data to determine if there were any significant differences in foraging efficiency among animals during pre-exposure, exposure and post-exposure, periods. Search time and handling time differed significantly

Table 4-33

Means (Standard Deviation) for Measurements of Foraging Behavior in White-Throated Sparrows During Seven Day Exposures to Microwaves at Power Densities 0.0, 0.1, 1.0, 10.0 and 25.0 mW/cm^2

Variable	Power Density (mW/cm^2)	Trials per E.P.	Mean (S.D.) Pre-expo.	Mean (S.D.) Exposure	Mean (S.D.) Post-expo.	P*
Number of Prey Eaten	0.0 [4]	12	4.5 (2.9)	5.9 (1.7)	5.1 (1.8)	-
	0.1 [2]	6	9.0 (1.5)	8.2 (2.5)	7.3 (1.0)	-
	1.0 [2]	6	7.0 (3.0)	8.2 (1.3)	7.5 (2.7)	-
	10.0 [2]	6	5.0 (1.9)	3.8 (2.2)	5.5 (0.5)	-
	25.0 [2]	6	3.5 (3.0)	6.0 (4.0)	5.7 (3.1)	-
Search Time (sec.)	0.0 [4]	12	104 (40)	77 (24)	81 (35)	-
	0.1 [2]	6	190 (87)	141 (57)	122 (37)	-
	1.0 [2]	6	79 (41)	104 (22)	100 (51)	-
	10.0 [2]	6	85 (58)	67 (48)	75 (42)	
	25.0 [2]	6	47 (46)	87 (73)	72 (34)	-
Handling Time (sec.)	0.0 [4]	12	37 (43)	49 (53)	38 (20)	-
	0.1 [2]	6	53 (11)	55 (18)	53 (18)	-
	1.0 [2]	6	33 (13)	50 (10)	42 (12)	-
	10.0 [2]	6	26 (15)	20 (14)	24 (4)	-
	25.0 [2]	6	20 (23)	56 (41)	38 (20)	-
Profitability	0.0 [4]	12	0.03 (.02)B**	0.05 (.02)A	0.04 (.01)A	<0.01
	0.1 [2]	6	0.04 (.02)	0.04 (.02)	0.04 (.01)	-
	1.0 [2]	6	0.06 (.01)	0.05 (.01)	0.06 (.01)	-
	10.0 [2]	6	0.05 (.02)	0.07 (.05)	0.06 (.02)	-
	25.0 [2]	6	0.04 (.03)	0.04 (.03)	0.05 (.02)	-
Search Efficiency	0.0 [4]	12	0.05 (.04)	0.07 (.02)	0.07 (.03)	-
	0.1 [2]	6	0.06 (.03)	0.07 (.04)	0.06 (.02)	-
	1.0 [2]	6	0.10 (.04)	0.08 (.03)	0.09 (.02)	-
	10.0 [2]	6	0.07 (.03)	0.10 (.09)	0.09 (.04)	-
	25.0 [2]	6	0.05 (.04)	0.08 (.07)	0.08 (.03)	-

[ ] = Number of birds on which observations were made.
E.P. = Exposure period.
* = Probabilities based on F values obtained from ANOVA.
** = Variation between periods was tested with Duncan's Multiple Range test. Reading horizontally, Means followed by the same letter are not significantly different (P = 0.05).

Table 4-34

Means (Standard Deviation) of Values for Foraging in White-Throated Sparrows During Four Week Continuous Exposure to Microwaves at Power Densities 0.0, 0.1, 1.0, 10.0 and 25.0 mW/cm^2

	Power	Means (S.D.)						
Variable	Density	N	Pre-exp.	N	Exposure	N	Post-exp.	P*
No. of Prey	0.0 [7]	14	5.4 (1.9)	27	4.4 (2.0)	14	4.1 (1.7)	-
	25.0 [10]	20	4.2 (1.8)	39	4.7 (2.1)	20	4.2 (1.8)	-
Search Time(s)	0.0 [7]	14	89 (37)A**	27	66 (39)AB	14	47 (32)B	<0.01
	25.0 [10]	20	69 (40)	39	69 (38)	20	73 (42)	-
Handling Time(s)	0.0 [7]	14	58 (26)A**	27	37 (21)B	14	37 (21)B	<0.01
	25.0 [10]	20	55 (28)	39	44 (26)	20	38 (28)	-
Profitability	0.0 [7]	14	.04 (.01)	27	.04 (.02)	14	.05 (.02)	-
	25.0 [10]	20	.04 (.01)	39	.04 (.01)	20	.04 (.02)	-
Search Eff.	0.0 [7]	14	.07 (.03)	27	.07 (.04)	14	.10 (.06)	-
	25.0 [10]	20	.08 (.07)	39	.08 (.04)	20	.07 (.03)	-

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* Probabilities based on F values obtained from ANOVA.

** Variation between periods was tested with Duncan's Multiple Range test. Reading horizontally, Means followed by the same letter are not significantly different (p = 0.05).

[ ] Number of birds.

($p<0.01$) among the periods for parallel sham controls (Table 4-34). Birds exposed to microwaves showed no significant differences in foraging efficiency, despite significant differences in ambient room and exposure chamber temperatures (Table 4-35).

Comparisons of environmental variables and foraging efficiency were made among pre-exposure, exposure and post-exposure measurements using Duncan's Multiple Range Test (Tables 4-34 and 4-35). In general, temperatures were significantly higher ($p<0.05$) during pre-exposure periods for parallel sham control birds. Sham irradiated birds exhibited the only significant differences in foraging efficiencies; therefore, since environmental conditions were similar for control and treated groups it does not appear that environmental conditions are the contributing factors. The significant differences in search time and handling time for parallel sham control (0.0 mW/cm^2 birds are undoubtedly attributed to random variation.

Four weeks of chronic microwave exposure seems to have no effect on foraging efficiency at a power density of 25.0 mW/cm^2.

Table 4-35

Means (Standard Deviations) of Values for Environmental Variables During Four Week Continuous Exposure to Microwaves at Power Densities 0.0 and 25.0 mW/cm^2

Variable	Power Density	N	Pre-exp.	N	Exposure	N	Post-exp.	P*
			Means (S.D.)					
Room temp °C t	0.0 [7]	14	19.4 (0.8)	27	19.8 (1.0)	14	20.5 (1.8)	- -
	25.0 [10]	20	19.8 (0.7)	39	19.8 (1.3)	20	20.2 (2.0)	- -
Room temp °C y	0.0 [7]	14	15.3 (1.9)B**	27	17.3 (1.8)A	12	18.2 (2.8)A	<0.005
	25.0 [10]	20	15.4 (2.2)C	39	17.9 (1.5)B	16	19.1 (2.2)A	<0.001
Room temp °C n	0.0 [7]	14	15.1 (1.6)C	27	17.0 (1.7)B	14	19.0 (2.4)A	<0.001
	25.0 [10]	20	15.5 (1.8)C	39	17.6 (1.6)B	20	19.5 (2.0)A	<0.001
Chamber temp °C y	0.0 [7]	14	15.8 (3.9)B	27	18.4 (2.3)AB	12	17.4 (1.3)A	<0.01
	25.0 [10]	20	16.5 (3.1)B	39	19.2 (1.9)A	16	18.1 (1.5)A	<0.001
Chamber temp °C n	0.0 [7]	14	15.8 (3.9)B	27	18.5 (2.9)A	14	19.2 (2.4)A	<0.001
	25.0 [10]	20	16.7 (4.3)B	39	19.8 (2.4)A	20	19.8 (2.3)A	<0.001
Relative Humidity	0.0 [7]	14	43 (12)B	27	53 (10)AB	14	47 (16)A	<0.05
	25.0 [10]	20	50 (9)B	39	63 (10)A	20	54 (14)B	<0.001

* Probabilities based on F values obtained from ANOVA.

** Variation between periods was tested with Duncan's Multiple Range Test. Reading horizontally, means followed by the same letter are not significantly different ($p<0.05$).

t Data taken from hydrothermograph.

y Data measured with YSI temperature probes.

n Data measured using Narda temperature probes.

[ ] Number of birds.

4.7 NESTING AND REPRODUCTION

4.7 NESTING AND REPRODUCTION

4.7.1 Reproductive Behavior (Zebra Finch)

4.7.1.1 Introduction

The proposed Satellite Power System will require a rectenna to receive microwave energy beamed down to earth. The rectenna is estimated to cover 100 square kilometers with the microwave field within the region of the rectenna ranging from 0.1 mW/cm^2 to 23 mW/cm^2 and this large area will be virtually impossible to close off to airborne biota. In view of this fact, if birds do enter and nest within the rectenna site, will their productive success be affected by the microwave field? The research presented in this section is directed at determining whether microwave exposure impairs reproductive behavior and success of Zebra Finches. In these experiments reproductive success was defined as the number of fledged offspring.

4.7.1.2 Methods

Observations on four breeding pairs of Zebra Finches, *Taeniopygia guttata*, were made initially on 7 January 1981 and two additional pairs on 9 February 1981. All pairs were observed until 7 May 1981. Each pair, prior to the initiation of the experiment, had successfully fledged a single brood containing two to three young. Each pair was housed in a microwave transparent cage (60 cm x 400 cm x 60 cm) constructed of plastic rods (1.8 cm in diameter) and 1.2 cm plastic mesh. A nest box (17 cm x 17 cm x 17 cm), constructed of the same material as the cages, was attached to an upper corner of each cage. The nest box was covered with black plastic film and provided with a cardboard floor and nest cup. Each cage had a single plastic perch (0.6 cm in diameter) across the width of the case. The perch was located 17 cm from the front of the case, and 22 cm from the cage floor. Feeders for seed, water and gravel were placed on a lower corner of the case on the side opposite the nest boxes. Cuttlebones were attached at one end of the perch to provide calcium. All feeders were plastic, and attached to the case netting with string. Small amounts of fresh vegetables, fruit and hardboiled eggs were placed on the case floor on squares of brown paper. Birds were fed *ad libitum* during the experiments.

Three pairs of Zebra Finches were exposed to 25 mW/cm^2 (two pairs from the January group and one of the two February pairs) and the remaining pairs served as controls in the experiment receiving no microwave radiation. The cages of the exposed birds were placed in one half of an exposure chamber (described elsewhere in the report) with the rear of the cages on the midline of the chamber. Cages were suspended from the ceiling with string at a height of 15 cm above the surface of the exposure chamber floor. The field density in the area occupied by cages ranged from 18 mW/cm^2 to 25 mW/cm^2. The lower values were measured at the lower edges and fronts of the cages.

The remaining three pairs of Zebra Finches, serving as a control, were placed in a chamber identical to that of the exposed birds and handled in an identical manner as the experimental group except that the cages were not suspended in air but rested on anechoic blocks which covered the chamber floor.

Each pair was observed daily for two 15-minute periods. Observations were made between 0900 and 1000 hours, and again between 1330 and 1430 hours. Behaviors of both members of the pair were recorded at thirty-second intervals. Bird behaviors were characterized as random, maintenance, feeding, reproductive, aggressive or thermoregulatory and are described below:

Random

Locomotion -- random movements around the cage which are not associated with activity such as nest building or aggression.

Alertness -- a stationary bird which shows a relatively sleeked posture, rapid head movements and often displays wing and tail movements.

Rest -- bird completely still, feathers fluffed, wings dropped.

Undirected singing -- male singing without orienting toward another bird.

Maintenance

Self-preening -- the bird cleans its body and/or feathers, often using shaking or scratching movements.

Allopreening -- the bird performs grooming activities on its mate.

Stretching -- bird stretches wing, or wings and leg. Activity not occurring within a preening episode.

Scratching -- bird scratches its body with a leg when not related to preening.

Shaking -- bird ruffles and shakes its feathers, activity not related to preening.

Sleep -- bird's feathers fluffed, and bird is sitting, eyes closed, head tucked.

Huddle -- both members of pair are fluffed and resting in contact with each other.

Beak wiping -- bird rubs side of beak against perch or side of cage. May be a cleaning action or a displacement behavior.

Feeding

Feeding -- eating, drinking or gravel ingestion.

Reproductive

Directed singing -- male bird sings while oriented to another bird.

Tail twisting -- male bird angles tail towards female, usually in conjunction with directed song.

Pivoting -- male movement as it approaches a female during courting.

Tail quivering -- bird lowers body and vibrates its tail during copulation or solicitation by either sex.

Copulation -- the act of mounting or mating.

Mandibulation -- rapid opening and shutting of mandibles.

Manipulation -- the handling or carrying of nesting material by the bird.

Nest building -- the act of adding materials to the nest.

Sitting/standing -- movement on and around the nest or nest site.

Incubation/brooding -- sitting on eggs or young.

Parental feeding -- providing food to nestlings.

Threat posturing -- characteristic low body posture oriented to another bird.

Aggressive

Supplanting -- one bird moving toward another bird causing it to move away.

Chasing -- aggressive pursuit of one bird towards another individual.

Beak fencing — birds stand upright, feathers sleeked, and fight with closed beaks.

Pecking -- one bird strikes at another individual with open or closed beak but not in the fencing posture.

Thermoregulatory

Gaping -- thermoregulatory behavior in which a bird opens its mandibles wide.

Panting -- rapid breathing of the bird with the beak open.

Wing Spreading -- feathers of bird sleeked, wings held away from body.

At each observation period the presence of a nest was noted and the number of eggs, hatchlings and fledglings present was recorded. After the normal incubation period, if hatching did not occur, all remaining eggs were opened to determine fertility.

4.7.1.3 Results

Table 4-36 (Appendix A4.7-1) shows a comparison of the reproductive success between the microwave exposed and non-exposed pairs of Zebra Finches. A Mann-Whitney test (level of significance $P = 0.05$) was used to test for differences between the groups. The number of clutches produced, eggs per clutch, fertile eggs per clutch, hatchlings per clutch, fledglings per clutch, and interval between clutches were not significantly different.

Time budgets of each group are compared in Table 4-37 (Appendix A4.7-2). A Mann-Whitney or t-test was used to compare the mean number of behavioral units allocated by the pair to each behavior category. One behavioral unit equals one observation during the 15-minute observation period; therefore, there are a total of 30 units per period for one individual and 60 units for the pair. The only significant difference observed between the microwave exposed birds and the control birds was the higher incidence of thermoregulatory behavior for the exposed birds.

4.7.1.4 Discussion

Birds exposed to microwave radiation (25 mW/cm^2) were able to breed

Table 4-36. Completed Clutches of Zebra Finch: Mean number of clutches per pair, eggs per clutch, hatchlings per clutch, fledglings per clutch and interval between clutches. Experimental group received 25 mW/cm^2 chronic microwave exposure.

	Control		Microwave		Sig.
	n	$\bar{x} \pm$ S.D.	n	$\bar{x} \pm$ S.D.	
Clutches per pair	3	5.7±1.2	3	4.0±2.0	
Eggs per clutch	17	5.6±1.1	12	5.3±2.2	
Fertile eggs per clutch	17	2.8±1.9	12	1.8±1.8	
Hatchlings per clutch	17	1.7±1.9	12	1.1±1.7	
Fledglings per clutch	17	1.0±1.8	12	0.8±1.3	
Interval between clutches, in days	14	20.8±12.8	9	30.7±18.1	

Table 4-37. Time Budgets of Zebra Finch. Activities of both (male and female) members recorded at 30 second intervals for 15 minute observation periods, giving a total of 60 behavioral units per observation session. Thermoregulatory states recorded in addition to the primary activity.

Behavior	Control $\bar{x} \pm$ S.D.	Microwave $\bar{x} \pm$ S.D.	Sig.
Random activity	17.5±27.61	23.6±14.29	
Maintenance behavior	5.9±6.98	7.6±11.32	
Feeding behavior	9.0±5.98	6.8±6.65	
Reproductive behavior	28.6±14.48	22.3±16.50	
Aggressive behavior	0.5±1.33	0.5±1.23	
Thermoregulatory behavior	0.03±0.22	2.4±5.23	P<.05
N of observation periods	260	267	

successfully. The data indicate that no differences in reproductive success exist between the continuously microwave exposed (25 mW/cm^2) and non-exposed Zebra Finches. Under these experimental conditions Taeniopygia guttata appears to be able to compensate for the differences in environmental factors caused by microwave irradiation.

Microwave exposed birds showed a higher level of Random Activity and Thermoregulatory behaviors than control birds. The presence of the microwave field and the increased temperature of the exposure chamber are obvious factors to be considered. It is not possible under the limitations of the present study to define which of the factors are major contributors to this behavior.

In conclusion, no notable effect of microwave exposure on behavior was observed.

4.7.2 Effect of Microwave Irradiation on Embryonic Development and Egg Hatchability

4.7.2.1 Introduction

This study was designed to determine the effects of microwave irradiation on fertile eggs. Eggs containing embryos were exposed twice daily to simulate worst case field conditions, i.e., where eggs would be exposed when incubating parents (microwave shields) are absent from the nest. The fertility, hatchability and growth of hatchlings of irradiated eggs were compared to those of non-irradiated eggs.

4.7.2.2 General Procedure

Three series of experiments were conducted. The first two contained eggs exposed to 25 mW/cm^2 microwaves, the third contained eggs exposed to 50 mW/cm^2. For each series, 152 Coturnix Quail (Coturnix coturnix) eggs were divided into four groups and incubated in a standard game bird incubator until hatching or for 19 days maximum (the Coturnix Quail has a 17-day incubation period) (Table 4-38). Groups I to III each consisted of 38 eggs that were removed from the incubator for two 30-minute periods each day. Group I eggs were irradiated with microwaves twice daily in an exposure chamber for 30 minutes; Group II eggs were not exposed to microwaves but rather to an air temperature comparable to that present in the exposure chamber for Group I; Group

Table 4-38. Treatments of Coturnix Quail Eggs in 3 Series of Experiments

Series* #	Group #	Microwave Power Density (mW/cm^2)	Ambient Conditions: Temperature (°C) ±S.D.	Ambient Conditions: Water Vapor Pressure (Torr) ±S.D.
1	1	25	23.1±1.60(n=33)	9.30±2.09(n=34)
	II	0	24.1±0.61(n-25)	5.84±2.19(n=14)
	III	0	20.3±1.28(n=32)	9.30±2.09(n=34)
	IV	0	37.5±0.09(n=23)	19.89±3.40(n=23)
2	I	25	21.4±1.35(n=28)	7.19±1.75(n=35)
	II	0	24.0±0.39(n=33)	3.53±1.06(n=33)
	III	0	18.3±1.39(n=28)	7.19±1.75(n=35)
	IV	0	37.4±0.38(n=35)	21.35±8.13(n=35)
3	I	50	22.7±3.06(n=34)	7.87±1.16(n=35)
	II	0	23.9±0.37(n=33)	4.53±0.96(n=33)
	III	0	19.6±1.02(n=24)	7.87±1.16(n=35)
	IV	0	37.4±0.37(n=34)	24.80±5.56(n=34)

*For each series, eggs form Groups I, II and III were removed from the incubator twice a day and subjected to listed treatments for 30 min. Group IV eggs remained in the incubator.

III eggs were incubated at room temperature for a time corresponding to the microwave exposure periods used in Group I; Group IV eggs were maintained in the incubator at 37.5°C for the entire experiment and were only removed to be weighed every four days.

Within the commercial incubator, the eggs were positioned on their small ends in cardboard trays and were automatically turned 60° back and forth every 2 hours. At the beginning of each of the 30-minute exposure periods, the trays containing Group I eggs were removed from the incubator, placed on a plastic mesh platform located in the center of a microwave exposure chamber and irradiated. The trays containing Group II eggs were placed in a second incubator maintained at 24°, and those holding Group III eggs in a control (non-exposed) chamber maintained at room temperature and the Group IV eggs were left in the incubator.

The ambient air temperature and relative humidity in the incubators were measured with a motorized psychrometer (Bendix Psychron, Model 566) and in the Rindge Avenue Microwave Irradiation Facility (RAMIF) with a wet/dry bulb sling psychrometer. The air temperature in the microwave and control exposure chambers were measured with a Narda Model 8011 RF Transparent Temperature Monitor. It was assumed that the water vapor pressure in the two exposure chambers was identical to that in RAMIF.

Eggs, in addition to those in Groups I to III, were used to monitor egg temperature with a RF transparent temperature monitor. A probe attached to a monitor was inserted into a small hole drilled into the shell and the probe tip positioned in the center of the egg. Evaporation and leakage of water and egg white around the probes were reduced by covering the area of the shell around the probe with petroleum jelly. For temperature measurements, new eggs were used every day to maintain as close as possible the thermal inertia of the original egg. Three eggs were placed into the 37.5°C incubator each day with Groups I, II, and III and were allowed to reach a temperature identical to that of the incubated eggs. The three eggs were then removed from the incubator and placed in the microwave chamber, control chambers and the 24°C incubator where the temperature probes were inserted into the eggs.

On the 16th day of incubation, 8 of the original 38 eggs were removed from each of the four groups and dried (intact) in an oven to constant mass. The remaining 30 eggs in each group were weighed on the 16th day and then returned to the incubator until hatching or day 19.

The conductance (G), the rate of movement of water through the shell of an intact quail egg maintained at constant temperature (incubator) was calculated using the following equation:

$$G = \dot{M}H_2O/(P_E - P_A) \qquad (1)$$

where $\dot{M}H_2O$ is the rate of the decrease in egg mass due to water loss through the shell (g/day), P_E is the saturation vapor pressure (Torr) of water inside the egg at the egg temperature and P_A is the vapor pressure (Torr) of water at the temperature of the air outside the egg. The fractional mass loss of an incubated egg (F) was computed from $\dot{M}H_2O$ using the following equation:

$$F = \dot{M}H_2O/M_e \qquad (2)$$

where I is the length of the incubation period (days) and M_e is the mass (g) of a freshly laid egg.

The microwave dosimetry study on bird eggs required the calculation of the specific heat of eggs and the heating rate of eggs under controlled environmental conditions. The specific heat for eggs was calculated by calorimetry. A hole (d = 1 mm) was drilled into the shell of four Coturnix Quail and 16 chicken eggs. A thermistor temperature sensor was placed in the center of each egg and was held in place with tape attached to the egg shell and thermistor lead. Each egg was then placed into a 45°C incubator. When an egg was heated to between 43-45°C, the egg was removed from the incubator and quickly plunged into a one liter wide-mouth glass Dewar flask containing cold water and a second thermistor probe. Immediately following the placement of the egg in the water, the mouth of the flask was closed with a polyethylene foam lid. The temperatures of the water and egg were recorded until the temperatures of the water and egg became equal and the experiment was terminated. The amount of water placed into the Dewar flask depended upon the species of egg; 0.1 liter for a quail egg and 0.2 liter for a chicken egg. A calorimeter constant of 39.2 g was calculated for the Dewar flask (see dosimetry section).

The specific heat of the egg was calculated by:

$$S = [(39.2 + m_2)(T_3 - T_2)]/[m_1(T_1 - T_3)] \qquad (3)$$

where m_1 is the mass of the egg (g), m_2 is the mass of water (g), T_1 is the initial egg temperature (°C), T_2 is the initial water temperature (°C), T_3 is the final temperature of the egg and water (°C) and S is the specific heat (cal/g/°C).

The heating rates of eggs were computed from the temperature rise of irradiated quail and chicken eggs. A hole (d = 0.001 m) was drilled into the shell of 16 quail eggs and 6 chicken eggs. A microwave transparent thermistor probe (Narda Model 8011 RF Transparent Temperature Monitor) was placed in the center of each egg and was held in place with tape attached to the egg shell and probe wire. Each egg was then placed (large end up) on a styrofoam platform which was supported by a plastic net suspended 0.025 m above the floor of a styrofoam box (0.40 x 0.28 x 0.105 m). The box had a 0.05 m thick wall. The styrofoam box was placed on a styrofoam platform suspended below the microwave irradiating horn in the exposure chamber. Each egg was irradiated by 92 mW/cm^2 until its temperature rose to 45°C. A linear regression model was fitted to the linear portion of the heating portion of the heating curve of each egg.

The specific absorption rate (S.A.R.) ($W/kg/mW/cm^2$) for eggs was calculated as:

$$S.A.R. = KLS/P$$

where K is a constant (69.769), L is the slope of the heating curve ($^{\circ}$C/min), S is the specific heat of the egg (cal/g/$^{\circ}$C) and P is the microwave power density (mW/cm^2).

4.7.2.3 Results

The typical patterns of temperature decline for irradiated and non-irradiated eggs during the 30-minute periods immediately following removal of the eggs from the 37.5°C incubator are illustrated in Figures 4-34 to 4-36. The temperature of three representative eggs removed from the incubator and maintained at room temperature (Group III) decreased exponentially to a temperature approximately 4°C above that of ambient (T_A) in 30 minutes. The temperature decline of the three Group III eggs could be approximated by the equation:

$$Y = 36.0\ e^{-0.15X}.$$

The temperature of a representative egg of Group II moved from the 37.5°C incubator and maintained at a temperature (T_A) comparable to eggs irradiated in the microwave exposure chamber, i.e., 24.0°C, also decreased exponentially ($Y = 34.9\ e^{-0.01X}$) to 25.4°C (Figure 4-36). Two eggs, irradiated with microwaves at a power density of 25 mW/cm^2 immediately upon removal from the 37.5°C incubator (Group I of Series 1 and 2), cooled to 7.8 (Figure 4-34) and 8.6°C (Figure 4-35) above ambient in 30 minutes. Data for the two eggs exposed to 25 mW/cm^2 could not be as closely fitted by an exponential curve as could the cooling curves for the eggs left at room temperature (Group III) in

Figure 4-34. Representative Temperature Declines of Coturnix Quail Eggs after Removal from Incubator (37.5°C) and Exposure to Microwaves at 0 and 25 mW/cm^2.

(1st Series)

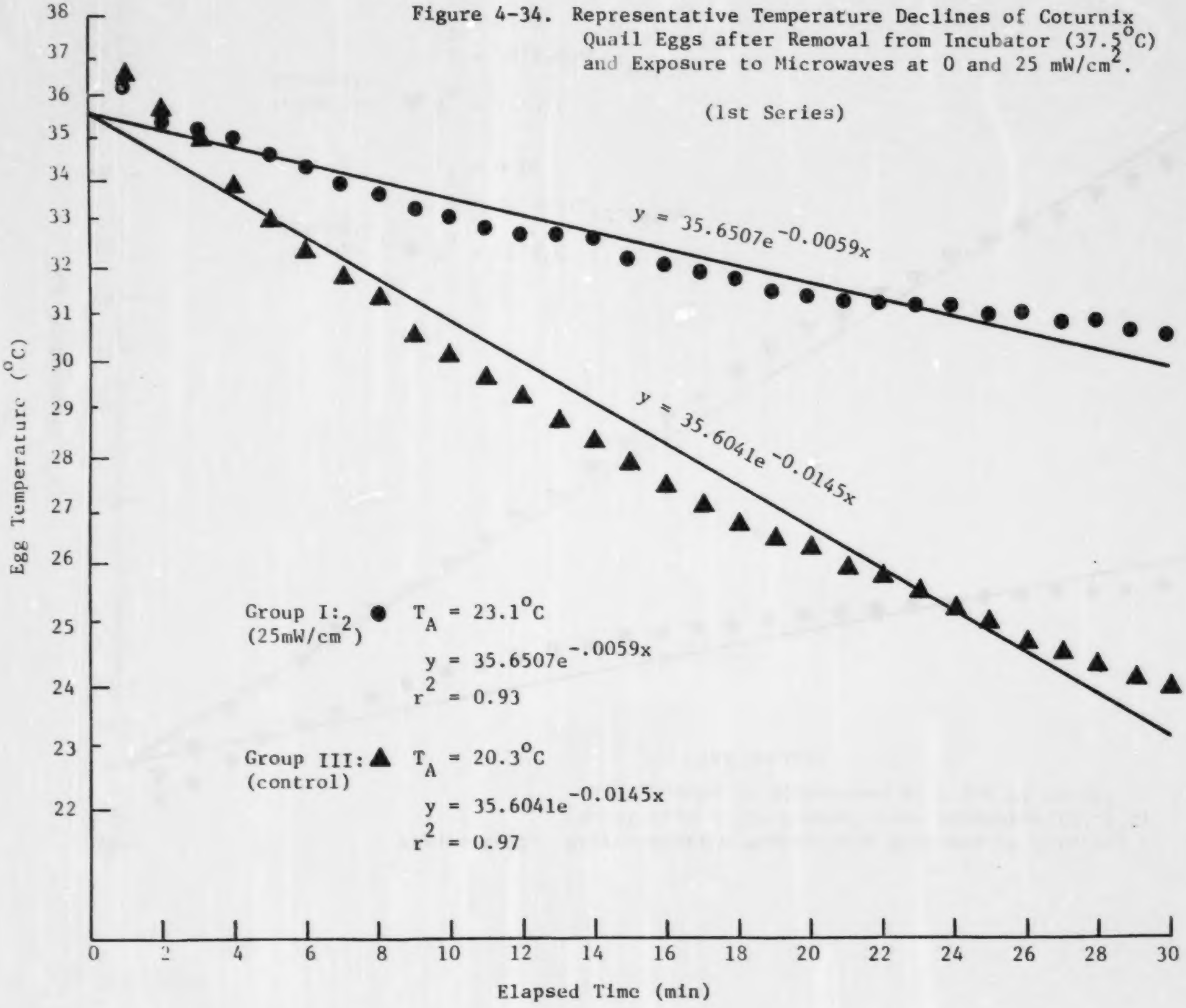
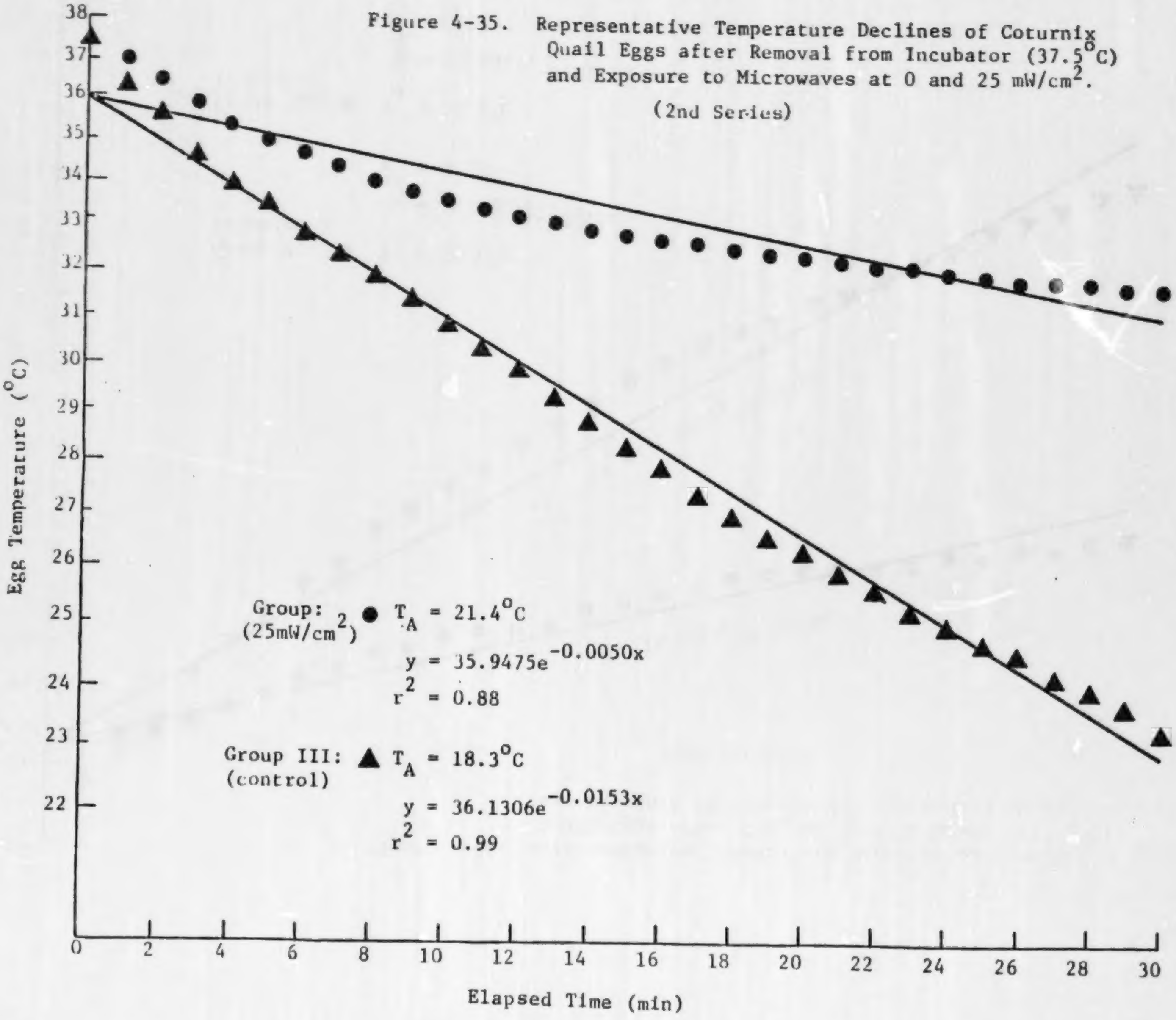


Figure 4-35. Representative Temperature Declines of Coturnix Quail Eggs after Removal from Incubator (37.5°C) and Exposure to Microwaves at 0 and 25 mW/cm². (2nd Series)



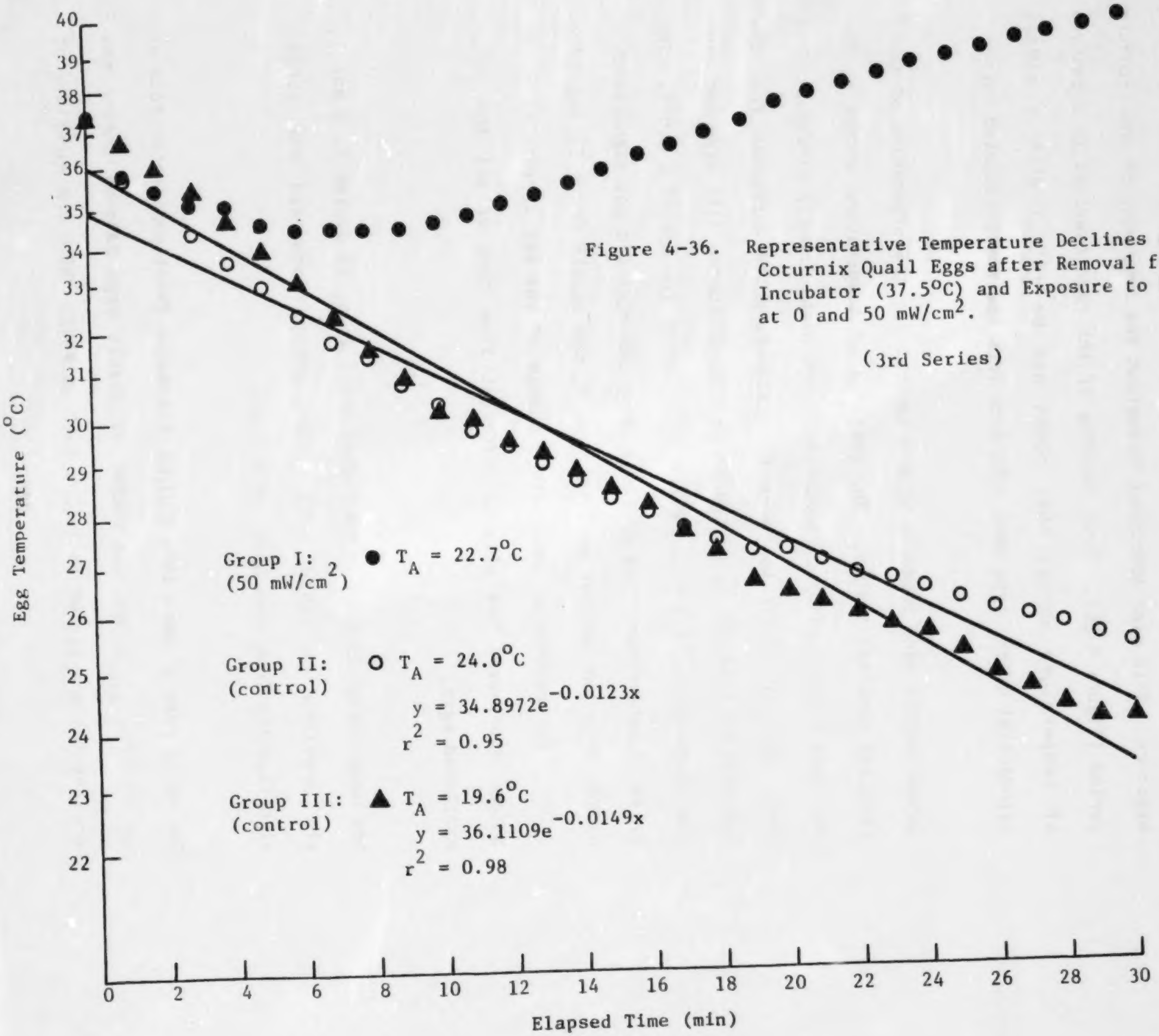


Figure 4-36. Representative Temperature Declines of Coturnix Quail Eggs after Removal from Incubator (37.5°C) and Exposure to Microwaves at 0 and 50 mW/cm^2.

(3rd Series)

Series 1 and 2 (Figures 4-34 and 4-35). The temperature of the eggs irradiated with microwaves at 50 mW/cm^2 dropped initially upon removal from the incubator, then started to rise within the first 10 minutes of exposure. This rise continued throughout the remainder of the exposure period (Figure 4-36). Thus, heating of the eggs resulted in a pattern of temperature change that could not be fitted with a simple exponential of the type used with data from the non-irradiated eggs.

Linear models were produced with a natural log transformation of the X (elapsed minutes) values. The patterns of temperature change in the two eggs irradiated by 25 mW/cm^2 were not significantly different from each other ($P > 0.05$) but were both significantly different from the temperature loss curves of the three control (Group III) eggs and from the temperature loss rate of the 24°C (Group II) egg ($P < 0.01$). The rates of temperature loss of the 3 Group III eggs did not significantly differ from one another or from that of the single Group II egg ($P > 0.05$). The pattern of temperature change of the egg irradiated by 50 mW/cm^2 microwaves was clearly different from that of all the other monitored eggs.

The mean losses in mass of incubated quail eggs, in Series 1, 2 and 3, are provided in Table 4-39. The group means did not differ significantly from each other ($P > 0.05$).

The daily rate of mass loss ($\dot{M}H_2O$), estimated fractional water loss at Day 17 ($F_{17\ days}$) and the number of viable eggs hatched during the three series are listed in Tables 4-40 to 4-42. With the exception of

Table 4-39. Loss of mass in Coturnix Quail eggs.

Series Number	Mean Weight Loss (g) ± S.D.				Analysis of Variance			
	Group I	Group II	Group III	Group IV	F	D.F. Among	D.F. Within	P Value
1	1.55 ± 0.37 (30)	1.66 ± 0.88 (30)	1.66 ± 0.88 (30)	1.67 ± 0.74 (30)	0.25	3	116	> 0.5
2	1.38 ± 0.37 (30)	1.26 ± 0.21 (29)	1.216 ± 0.22 (30)	1.33 ± 0.38 (30)	1.59	3	115	> 0.1
3	1.31 ± 0.39 (30)	1.40 ± 0.55 (30)	1.39 ± 0.55 (30)	1.45 ± 0.62 (30)	0.35	3	116	> 0.5

( ) = n

Table 4-40. The relationship between egg water loss and hatching success of irradiated and non-irradiated Coturnix Quail eggs under four experimental treatments (1st series)[1]

Group	n	T_A[2] (°C)	Mean Egg Mass (± C.L.) Initial (g)	Mean Egg Mass (± C.L.) 16 Day (g)	Water Loss M_{H_2O} (g/day)	Water Loss $F_{17\ Days}$[3] (%)	Viable Eggs # Hatch	Viable Eggs #Not Hatch	P Value[5]
I[4]	30	23.1	11.38 (0.43)	9.83 (0.45)	0.10	14.47	18 (X^2 = 1.40)	4	> 0.2
II	30	24.1	10.86 (0.33)	9.20 (0.53)	0.10	16.24	19 (X^2 = 2.80)	3	> 0.1
III	30	20.3	11.23 (0.29)	9.53 (0.57)	0.11	16.08	18 (X^2 = 0.89)	11	> 0.2
IV	30	37.5	11.02 (0.45)	9.26 (0.41)	0.11	16.97	17	7	

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[1] Eggs from Groups I to III were removed from incubator twice a day and treated to ambient temperatures below 37.5°C for 30 min. Group IV eggs remained in the incubator.

[2] T_A = mean temperature.

[3] $F_{17} = M_{H_2O} \times 17$ days/initial mass

[4] Eggs in Group I were irradiated by 25 mW/cm^2 microwaves during treatment.

[5] The proportions of viable eggs in Groups I - III that hatched were tested for significant differences from that of Group IV (X^2, d.f. = 1).

Table 4-41. The relationship between egg water loss and hatching success of irradiated and non-irradiated Coturnix Quail eggs under four experimental treatments (2nd series)[1]

			Mean Egg Mass (± C.L.)		Water Loss		Viable Eggs		
Group	n	T_A[2] (°C)	Initial (g)	16 Day (g)	M_{H_2O} (g/day)	$F_{17\ Days}$[3] (%)	# Hatch	# Not Hatch	P Value[5]
I[4]	30	21.4	10.86 (0.43)	9.49 (0.42)	0.09	13.40	20	4 (X^2 = 1.86)	> 0.1
II	29	22.6	10.53 (0.33)	9.26 (0.34)	0.08	12.81	23	1 (X^2 = 0.59)	> 0.2
III	30	18.3	10.72 (0.37)	9.50 (0.38)	0.08	12.09	23	2 (X^2 = 0.23)	> 0.5
IV	30	37.4	11.06 (0.38)	9.73 (0.43)	0.08	12.78	21	2	

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[1] Eggs from Groups I to III were removed from incubator twice a day and treated to ambient temperatures below 37.5°C for 30 min. Group IV eggs remained in the incubator.

[2] T_A = mean temperature.

[3] $F_{17} = M_{H_2O}$ x 17 days/initial mass.

[4] Eggs in Group I were irradiated by 25 mW/cm^2 microwaves during treatment.

[5] The proportions of viable eggs in Groups I - III that hatched were tested for significant differences from that of Group IV (X^2, d.f. = 1).

Table 4-42. The relationship between egg water loss and hatching success of irradiated and non-irradiated Coturnix Quail eggs under four experimental treatments (3rd series)[1]

			Mean Egg Mass (± C.L.)		Water Loss		Viable Eggs		
Group	n	T_A[2] (^oC)	Initial (g)	16 Day (g)	M_{H_2O} (g/day)	$F_{17\ Days}$[3] (%)	# Hatch	# Not Hatch	P Value[5]
I[4]	30	22.7	11.23 (0.40)	9.92 (0.42)	0.08	12.39	6 (X^2 = 21.32)	13	< 0.01
II	30	23.9	11.08 (0.34)	9.68 (0.39)	0.09	13.43	17 (X^2 = 0.82)	4	> 0.2
III	30	19.6	10.96 (0.38)	9.57 (0.46)	0.09	13.48	13 (X^2 = 0.95)	7	> 0.2
IV	30	37.4	11.10 (0.39)	9.65 (0.43)	0.09	13.88	17	6	

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[1] Eggs from Groups I to III were removed from incubator twice a day and treated to ambient temperatures below 37.5°C for 30 min. Group IV eggs remained in the incubator.

[2] T_A = mean temperature.

[3] $F_{17} = M_{H_2O}$ x days/initial mass.

[4] Eggs in Group I were irradiated by 50 mW/cm^2 microwaves during treatment.

[5] The proportions of viable eggs in Groups I - III that hatched were tested for significant differences from that of Group IV (X^2, d.f. = 1).

Group I in Series 3 (50 mW/cm^2) (Table 4-42), Groups I, II and III in each series did not differ in hatching success from that of the corresponding eggs in Group IV that were incubated continuously. The 30 eggs in Group I of Series 3, irradiated with microwaves at 50 mW/cm^2 during the two daily 30-minute exposures, had a significantly lower hatching success than did eggs of Group IV in the treatment series ($X^2 = 21.32$, d.f. = 1, $P < 0.05$) (Table 4-42). Hatching success was insensitive to fractional mass losses between 12 and 16 percent of the initial mass.

The ambient temperatures (T_A), relative humidities (RH), estimated mean ambient water vapor pressures (P_A), the estimated water losses for 17 hours of treatment with and without microwaves and estimated 17-day water losses for the eggs treated in each of the three series are summarized in Tables 4-43 to 4-45. The ambient water vapor pressure for Groups I and III in all series was assumed to be equal to that calculated for RAMIF from measured ambient temperature and relative humidity values. Estimates of water loss for the 17 h of actual treatment were calculated with Equation (1). The maximum and minimum estimates for all treatment groups for each of the series were calculated from an assumed egg temperature of 37.5°C or T_A, respectively. The probable estimates of water loss for 17 h were calculated from the egg temperatures at the 16th minute of the temperature profiles illustrated in Figures 4-34 to 4-36. The computed water vapor conductances for Group IV in each of the three series (0.0038 g/day/Torr for Series I, 0.003 for Series II, and 0.0039 for Series III) were used to compute all estimated 17 h water losses for

Table 4-43. Predicted and Observed Water Loss of Irradiated and Non-irradiated Coturnix Quail Eggs (Series #1).

	Environmental Conditions			Predicted Water Loss for 17h of Actual Treatment			Predicted Water Loss for 17 Days
Treatment Groups	T_A (°C)	RH (%)	P_A (Torr)	Maximum[2] (g/17h)	Minimum[3] (g/17h)	Probable[4] (g/17h)	(g/17 days)[5]
I $\bar{x}$ (n) (SD)	23.1 (35) (1.56)	— — —	9.59[6] (36) (1.48)	0.105	0.032	0.062	1.65
II	24.1 (25) (0.61)	25.2 (14) (9.47)	5.84 (14) (2.19)	0.163	0.045		1.76
III	20.3 (32) (1.28)	— — —	9.59[6] (36) (1.48)	0.105	0.023	0.034	1.81
IV	37.5 (23) (0.09)	41.0 (23) (6.96)	19.89 (23) (3.40)	0.055	0.055		1.83

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[1] Treatment groups (two 30-minute exposures per day):

I: 25 mW/cm^2, T_A = 23.1°C.

II: T_A = 24.1°C.

III: T_A = 20.3°C.

IV: T_A = 37.5°C.

[2] Estimate based on T_{egg} of 37.5°C.

[3] Estimate based on T_{egg} equal to T_A.

[4] Estimate based on T_{egg}(I) = 30.4°C and T_{egg}(III) = 23.9°C (Fig. 4-34).

[5] M_{H_2O} X 17 days

[6] Estimate based on ambient RH measured in RAMIF

Table 4-44. Predicted and Observed Water Loss of Irradiated and Non-irradiated Coturnix Quail Eggs (Series #2).

Environmental Conditions				Predicted Water Loss for 17h of Actual Treatment			Predicted Water Loss for 17 Days
Treatment Groups	T_A (°C)	RH (%)	P_A (Torr)	Maximum[2] (g/17h)	Minimum[3] (g/17h)	Probable[4] (g/17h)	(g/17 days)[5]
I $\bar{x}$	21.4	—	7.19[6]	0.087	0.025	0.070	1.46
(n)	(28)	—	(35)				
(SD)	(1.35)	—	(1.75)				
II	24.0	15.8	3.53	0.095	0.040		1.35
	(33)	(33)	(33)				
	(0.39)	(4.37)	(1.06)				
III	18.3	—	7.19[6]	0.087	0.018	0.045	1.30
	(28)	—	(35)				
	(1.39)	—	(1.75)				
IV	37.4	44.2	21.35	0.057	0.057		1.41
	(35)	(35)	(35)				
	(0.381)	(16.89)	(8.13)				

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[1] Treatment groups (two 30-minute exposures per day):

I: 25 mW/cm^2, T_A = 21.4°C.
II: T_A = 24.1°C
III: T_A = 20.3°C.
IV: T_A = 37.4°C.

[2] Estimate based on T_{egg} of 37.4°C.

[3] Estimate based on T_{egg} equal to T_A.

[4] Estimate based on T_{egg}(I) = 32.7°C and T_{egg}(III) = 27.9°C (Fig. 4-35).

[5] M_{H_2O} X 17 days

[6] Estimate based on ambient RH measured in RAMIF

Table 4-45. Predicted and Observed Water Loss of Irradiated and Non-irradiated Coturnix Quail Eggs (Series #3).

Environmental Conditions				Predicted Water Loss for 17h of Actual Treatment			Predicted Water Loss for 17 Days
Treatment Groups	T_A (°C)	RH (%)	P_A (Torr)	Maximum[2] (g/17h)	Minimum[3] (g/17h)	Probable[4] (g/17h)	(g/17 days)[5]
I $\bar{x}$	22.7	—	7.87	0.111[6]	0.035	0.102	1.39
(n)	(34)	—	(35)				
(SD)	(3.06)	—	(1.16)	0.120			
II	23.9	20.2	4.53	0.120	0.049	0.065	1.49
	(33)	(33)	(33)				
	(0.37)	(4.14)	(0.96)				
III	19.6	—	7.87	0.111[6]	0.036	0.080	1.48
	(24)	—	(35)				
	(1.02)	—	(1.16)				
IV	37.4	50.9	24.8	0.065	0.065		1.54
	(34)	(34)	(34)				
	(0.37)	(11.06)	(5.56)				

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[1] Treatment groups (two 30-minute exposures per day):

I: 50 mW/cm^2, T_A = 22.7°C.
II: T_A = 23.9°C.
III: T_A = 19.6°C.
IV: T_A = 37.4°C.

[2] Estimate based on T_{egg} of 37.4°C.

[3] Estimate based on T_{egg} equal to T_A.

[4] Estimate based on $T_{egg}(I)$ = 36.1°C, $T_{egg}(II)$ = 27.9°C, $T_{egg}(III)$ = 28.0°C (Fig. 4-36).

[5] M_{H_2O} X 17 days

[6] Estimate based on ambient RH measured in RAMIF

Groups I to III from each series. This was necessary as only Group IV eggs were held under constant temperature. The water loss for 17 days was calculated from $\dot{M}H_2O$. No relationship was observed between the predicted water losses for the 17 h of actual treatment (predicted from ambient temperature and humidity) and the water loss estimates for 17 days (estimated from water loss rates over 16 day period Tables 4-43 to 4-45).

The mean masses of shells from eggs in Series 3 are summarized in Table 4-46. These were eggs that had been removed from each treatment group and dried to constant mass after 16 days of incubation. The mean masses of shells from Groups I-IV in Series 3 and of control (non-incubated) eggs did not differ significantly ($F = 0.09$; d.f. = 4, 54; $P = 0.9$). Apparently, the embryos exposed to the four treatments did not differ in their ability to absorb calcium from the egg shells to support bone growth.

At the end of Series 1 experiments, eggs in Group IV hatched on the average approximately 12 h before the eggs in Group I. Group II hatched 6 h, and Group III, 12 h before the eggs in Group I. At the end of Series 2, Groups I and II eggs hatched approximately 12 h after eggs in Group IV. Group III followed Group IV by 24 h. After the 3rd series, Group IV started to hatch first, followed 6 h later by Group I. Groups II and III hatched between 12 and 18 h after Group IV.

The specific absorption rate (S.A.R.) calculated for Coturnix Quail eggs irradiated on their large ends by 92 mW/cm^2 microwaves was 0.50 $W/kg/mW/cm^2$ and the S.A.R. of chicken eggs irradiated in the same

Table 4-46. Effect of Microwave on Egg Shell Mass - Series III.

	Mean Egg Shell Mass (g)					Sig
	Group I[2]	Group II[3]	Group III[4]	Group IV[5]	Control	Among Groups P Value
mean	1.018	1.019	1.030	0.996	1.003	
±SD	±0.229	±0.097	±0.114	±0.134	±0.124	>0.5
(n)	(6)	(7)	(7)	(8)	(30)	

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[1] Eggs from Groups I - III were removed from incubator twice a day and were exposed to ambient temperatures below 37.5°C for 30 minutes. Group IV eggs remained in the incubator.

[2] $\bar{x}\ T_A = 22.7°C$, $\bar{x}\ P_A = 7.87$ Torr, 50 mW/cm^2.

[3] $\bar{x}\ T_A = 23.9°C$, $\bar{x}\ P_A = 4.53$ Torr.

[4] $\bar{x}\ T_A = 19.6°C$, $\bar{x}\ P_A = 7.87$ Torr.

[5] $\bar{x}\ T_A = 37.4°C$, $\bar{x}\ P_A = 24.80$ Torr.

manner was 0.28 W/kg/mW/cm^2 (Table 4-47). This difference in computed S.A.R. for quail and chicken eggs was primarily due to measured differences in rate of temperature rise of the two egg species; 0.74°C/min for quail and 0.44°C/min for chicken (Table 4-47, Appendix A4.7-3), rather than do differences in specific heats (Appendix A4.7-4).

4.7.2.4 Discussion

The natural variability in water vapor conductance of Coturnix Quail eggs appears to be sufficiently great to mask any differences in mass loss that could be induced by the four treatments in any of the three series. Irradiation by 25 mW/cm^2 microwaves alters the normal exponential decline in temperature typical of eggs removed from a 37.5°C incubator. Within the 30 minutes allotted for an exposure to microwaves in this study, 25 mW/cm^2 does not cause a rise in egg temperature, only a lessening of the rate of cooling when T_A is below 24°C. If exposures were lengthened to an hour, it is likely that eggs exposed to 25 mW/cm^2 would eventually show a rise in temperature as did the eggs exposed to 50 mW/cm^2.

The reduced hatchability resulting from irradiation by 50 mW/cm^2 does not appear to be due to desiccation or to a reduced ability of the embryos to incorporate egg shell calcium for bone growth. Rather, it is most likely that some of the embryos irradiated by 50 mW/cm^2 died of hyperthermia. At the end of the microwave exposure period, these embryos reached temperatures of 40°C or higher.

Table 4-47. Specific absorption rates (S.A.R.) for Coturnix Quail and chicken eggs.[1]

Species	Slope of Heating Curve (L)		Specific Heat (S)		Specific Absorption Rate (S.A.R.)
	Egg Mass (g) (n, S.D.)	L (°C/min) (n, S.D.)	Egg Mass (g) (n, S.D.)	S(cal/g/°C) (n, S.D.)	$W/kg/mW/cm^2$
Quail	9.65 (16, 0.53)	0.74 (16, 0.12)	10.22 (4, 0.67)	0.89 (4, 0.05)	0.50
Chicken	60.23 (6, 1.04)	0.44 (6, 0.02)	63.51 (16, 3.57)	0.83 (16, 0.03)	0.28

[1] Eggs rested with their large ends up and were irradiated from above.

[2] S.A.R.'s computed by the following equation:

$$S.A.R. = KLS/P$$

where $K = 69.769$ and $P = 92\ mW/cm^2$.

It can be concluded that repeated thirty minute exposures of eggs to 25 mW/cm^2 microwaves will not reduce hatchability of eggs in the field provided that, 1) the eggs are shielded from microwaves by the parent birds the remaining 23 hours of the day, 2) they are shielded from direct solar radiation by cover such as vegetation when the parent birds are off the nest and, 3) the air temperature does not rise above 24°C when the eggs are being irradiated by microwaves. Irradiation at a power density of 50 mW/cm^2 may well reduce hatchability in the field, particularly if the air temperature rises above 23°C and the eggs are shielded from the wind.

Eggs exposed in the field to 25 mW/cm^2 microwaves when the incubating parent leaves the nest to forage may hatch slightly sooner than those that are not irradiated. If shorter incubation times produce an earlier fledging of chicks that hatch, irradiation would produce a slight ecological benefit for both parent and eggs by reducing their period of vulnerability to predators. The reduced hatchability of eggs exposed to 50 mW/cm^2 would probably outweigh any slight increase in reproductive fitness to the parent bird that would be related to a shorter hatching time.

Ten gram quail eggs irradiated with microwaves at 25 and 50 mW/cm^2 (2.45 GHz) would absorb 0.125 W (12.5 W/kg) and 0.25 W (25 W/kg), respectively. During a 30-minute exposure, a Coturnix Quail egg irradiated by 25 mW/cm^2 would absorb approximately 225 J and an egg exposed to 50 mW/cm^2, 450 J. Eggs positioned with their long axes perpendicular to the microwave beam would presumably have absorbed more energy. The higher S.A.R. of 10 g Coturnix Quail eggs as compared with that of the 60 g chicken eggs suggests that the S.A.R. of eggs is inversely proportional to mass. If this is true, the tiny eggs of passerine birds may be more susceptible to heating by 2.45 GHz microwave radiation.

4.7.3 Growth of Quail Hatchlings

4.7.3.1 Introduction

Bird embryos that are irradiated by microwaves may hatch normally and yet show developmental deformities or retarded growth after hatching. We therefore monitored post-hatching growth of Coturnix Quail chicks that had been irradiated as embryos or had served as controls in the hatchability experiment.

4.7.3.2 Procedure

Within 12 hours of hatching, all chicks that hatched from eggs in the Series 2 and 3 experiments were removed from the incubator and placed in a standard commercial brooder. All birds were given food (Turkey Starter) and water *ad libitum*. Each bird from Series 2 was weighed to the nearest 0.1 g every 2-3 days for 26-28 days post-hatching and the chicks from Series 3 were weighed every 2-3 days for 15 days after hatching.

4.7.3.3 Results and Discussion

A linear least squares regression model was fitted to the hatchling growth data from Groups I to IV, of Series 2 and 3. The slope of the 26-day growth curve for those chicks that had been irradiated as embryos by 25 mW/cm^2 microwaves (Series 2, Group I) was not significantly different from the slope of the growth curve of chicks, from embryos kept at 24°C (Series 2, Group II) chicks, kept at room temperature (Series 2, Group III) or of those chicks from embryos kept in the incubator during the 17-day incubation period (Series 2, Group IV) ($P > .05$).

Similarly, the slope of the 15-day growth curve of those chicks that had been irradiated twice daily (when in the egg) by 50 mW/cm^2 microwaves (Series 3, Group I) was not significantly different from the slope of the growth curve of 24°C chicks (Series 3, Group II), room temperature chicks (Series 3, Group III) or the continuous incubation chicks (Series 3, Group IV) ($P > .05$).

Comparisons of the slopes of the growth curves from Series 2 were compared to those of Series 3. No significant differences were noted in the rates of growth of the 25 and 50 mW/cm^2 chicks (Group I of Series 2 and 3) or between those of Groups II (24°C), Groups III (room temperature) or between Groups IV (continuous incubation) ($P > .05$).

No deformed chicks were observed from eggs that had been microwave irradiated at 25 or 50 mW/cm^2.

These data suggest that if a bird manages to hatch successfully from an egg that had been irradiated twice daily for 30 minutes for 17 days, it will grow normally. As we did not follow chicks far beyond 28 days post-hatching, we do not know whether deformities, etc., would have arisen later in life.

4.8 EFFECT OF MICROWAVE IRRADIATION ON BIRD FLIGHT

4.8.1 Introduction

This study was designed to determine the effects of microwave irradiation on birds in flight. Budgerigars (Melopsittacus undulatus) were trained to fly in an average 37 km/h wind during exposure to microwaves at power densities of zero (control) and 50 mW/cm^2. The flight duration, mid- and post-flight thermoregulatory behavior and pre- and post-flight body temperatures of budgerigars flown during exposure to microwave irradiation were compared to those flown under control conditions.

4.8.2 General Procedure

Budgerigars were trained to fly in a flight cage (1.04 x 0.63 x 0.63 m) placed into a 37 km/h wind produced by a wind tunnel. A cross sectional wind speed profile measured in a vertical plane midway down the length of the flight cage is illustrated in Figure 4-37. As the budgerigars did not fly in the area close to walls, it is estimated that the birds flew in wind with a mean speed of 37.2 km/h. The flight cage contained one removable perch that spanned the center of the cage perpendicular to the wind direction.

The top, bottom, and two sides of the flight cage consisted of plexiglass sheets (0.6 cm thickness). The front, back and bottom were strung with stainless steel wires (1.6 mm) spaced at one centimeter intervals. This wire grid was electrified by connecting alternate wires to either a positive or negative lead of a high voltage (5500 V) DC

Figure 4-37. SPEED[+] (km/h) OF AIR THROUGHOUT THE FLIGHT CAGE

Top of Cage

0.63 m

0.63 m

									$\bar{X}$	(SD)	CV (%)
	22.86	26.52	25.60	25.60	27.43	29.26	32.00	29.26	27.3	(2.8)	10.2
	27.43	30.18	30.18	32.00	32.92	34.75	35.66	33.83	32.1	(2.7)	8.4
	29.26	32.00	32.00	35.66	34.75	36.58	35.66	33.83	33.7	(2.5)	7.4
	35.66	35.66	34.75	43.89	40.23	42.06	41.15	38.40	38.9	(6.2)	15.9
	35.66	39.32	40.23	47.55	50.29	43.89	41.15	41.15	42.4	(4.7)	11.1
	39.32	44.81	44.81	43.89	43.89	41.15	38.40	39.32	41.9	(2.7)	6.4
	32.92	32.92	31.09	31.09	30.18	28.35	26.52	27.43	30.0	(2.4)	8.0
	21.03	21.03	18.29	20.12	18.29	16.46	16.46	18.29	18.7	(1.8)	9.6
$\bar{X}$	30.5	32.8	32.1	35.0	34.7	34.1	33.4	32.7	33.1		
SD	6.5	7.4	8.2	9.6	10.0	9.1	8.4	7.5			
CV(%)	21.3	22.4	25.0	27.6	28.9	26.8	25.1	23.1			

[+] Measurements were made in a vertical plane mid-way between front and back of flight cage. Enclosed values were used to estimate the mean wind speed of 37.2 km/min (n = 36, SD = 5.92, CV = 15.9%).

current power source (< 1 milliampere). The grid was used during training and experimentation of budgerigars to maintain flight as any bird that attempted to land would usually touch adjacent wires and receive a shock.

Each bird was trained to begin flight when the perch was withdrawn and the wind simultaneously turned on. Each bird's endurance was gradually increased to at least 10 minutes. The use of a high voltage grid proved to be essential for training and maintaining continuous flight as each bird would occasionally touch the bottom of the cage during a flight and would immediately land if the power to the grid was off.

Initially, the goal was to train birds to fly continuously for 30 minutes. Over a period of 11 months, this proved successful in only one instance. Thus, it was necessary to reduce the required flight time in order to carry out experiments. A flight time of 10 minutes was then chosen to permit a comparison of results to those obtained in experiments on thermoregulatory behavior and body temperature changes in Blue Jays and House Finches. In view of the long training periods and unfortunate deaths of two well trained birds, each budgerigar was used repeatedly in the flight experiment until the bird died or learned how to avoid the shock by perching on the same or adjacent wires of the same polarity.

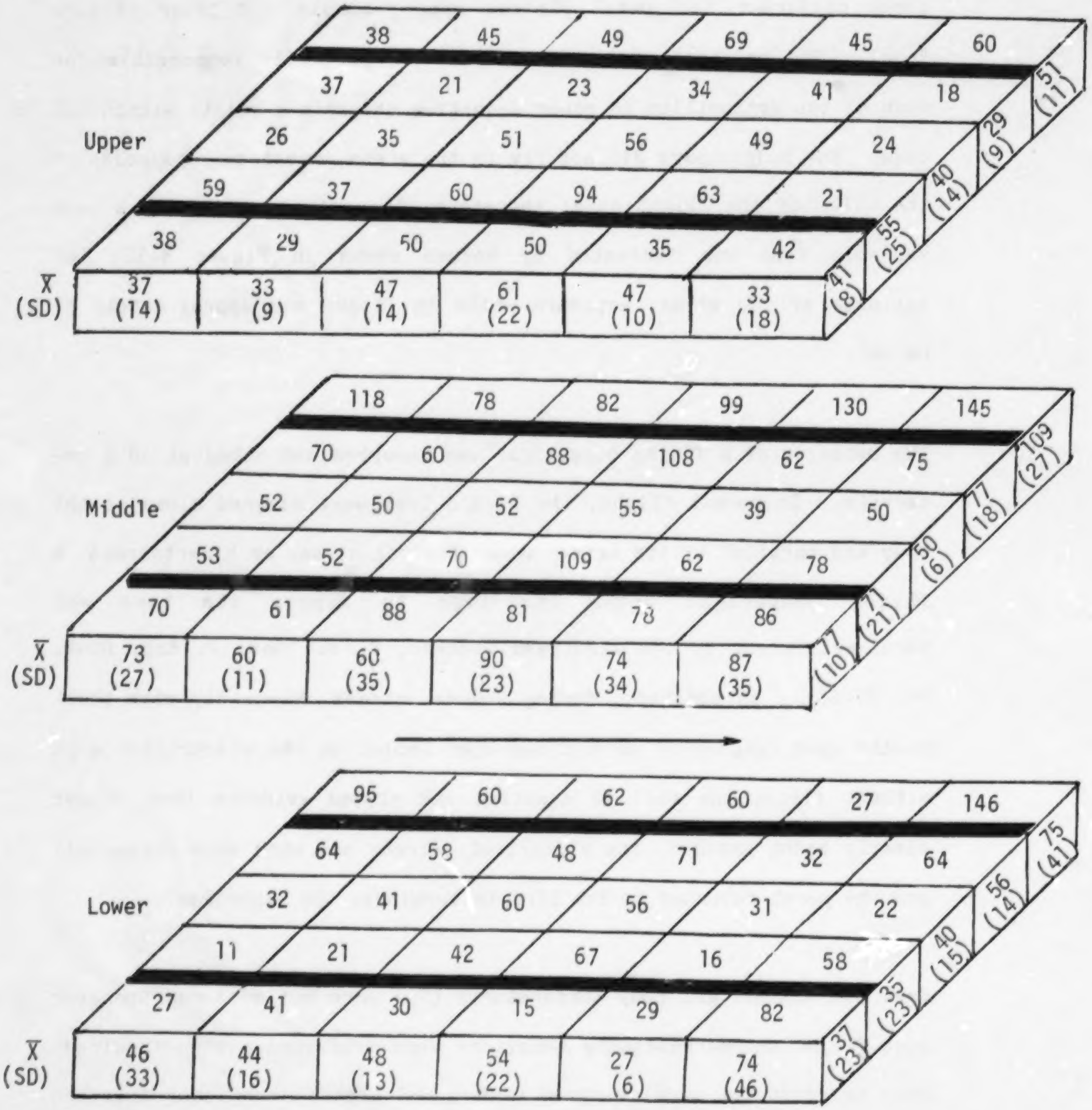
Each experimental subject was flown for two 10 minute periods a day; a control flight and a microwave flight with a minimum of 30 minutes of rest between the flights. After an initial training period, the flight cage was placed inside a microwave exposure chamber (#5). The microwave power density of the field in the flight cage was measured in three different horizontal planes; upper, middle and lower (Figure 4-38). The presence of the wire grid was partially responsible for much of the variability in power densities at various points within the cage. The budgerigars did not fly in the areas immediately adjacent to the walls of the flight cage; therefore, the actual exposure was less variable than was indicated by values shown in Figure 4-38. Our estimate of the birds; exposure while in flight was approximately 51 mW/cm^2.

The behavior of a flying budgerigar was observed and noted at 10 s intervals. In normal flight, the bird's legs were aligned close to the body and parallel to its axis. Under thermal stress or hyperthermia, a flying budgerigar drops its legs to expose its toes and tarsa-metatarsus to the airstream (Tucker, V. A. 1968. J. Exp. Biol. 48: 67-87). In addition, during thermal stress, birds fly with their mouths open (gaping). If a budgerigar landed on the electrified grid without flying the full 10 minutes, and showed evidence that it was clearly being shocked, the electrical current and wind were turned off and the perch returned to the bird to terminate the experiment.

Pre- and post-flight body temperatures (T_B) were not measured whenever post-flight thermoregulatory behaviors were monitored. When required, body temperatures were measured with a calibrated thermistor inserted 1.5 cm into the cloaca. Measurement of body temperature was made immediately before a bird was placed into the flight cage and then

Figure 4-38

DISTRIBUTION OF MICROWAVE POWER DENSITIES+ IN FLIGHT CAGE



Upper

	38	45	49	69	45	60	51 (11)
	37	21	23	34	41	18	29 (9)
	26	35	51	56	49	24	40 (14)
	59	37	60	94	63	21	55 (25)
	38	29	50	50	35	42	41 (8)
X̄ (SD)	37 (14)	33 (9)	47 (14)	61 (22)	47 (10)	33 (18)	

Middle

	118	78	82	99	130	145	109 (27)
	70	60	88	108	62	75	77 (18)
	52	50	52	55	39	50	50 (6)
	53	52	70	109	62	78	71 (21)
	70	61	88	81	78	86	77 (10)
X̄ (SD)	73 (27)	60 (11)	60 (35)	90 (23)	74 (34)	87 (35)	

Lower

	95	60	62	60	27	146	75 (41)
	64	58	48	71	32	64	56 (14)
	32	41	60	56	31	22	40 (15)
	11	21	42	67	16	58	35 (23)
	27	41	30	15	29	82	37 (23)
X̄ (SD)	46 (33)	44 (16)	48 (13)	54 (22)	27 (6)	74 (46)	

+Measurements (mW/cm^2) were made in three horizontal planes along the flight cage parallel to the wind direction (as viewed from the top of the cage). The cage dimensions were 0.63 m wide and 1.04 m in length. Power density values from the middle three rows of each horizontal plane used to compute the mean power density of 50.5 mw/cm^2 (n = 54, SD = 20.06, CV = 43.7%)

again as soon as it could be captured and removed from the flight cage -- usually within 10 seconds after the wind was turned off.

Thermoregulatory behavior after flight was ranked according to severity, into five different patterns.

I. Mild stress when birds show discontinuous panting at approximately 120 breaths per minute.

II. Discontinuous panting with mouth movements slightly more pronounced than in pattern I and slight wing spreading.

III. Continuous heavy panting, discontinuous spreading of wings and light vertical bobbing of the tail.

IV. Continuous heavy panting, continuous spreading of wings held more or less fully open.

V. Severe stress when birds show continuous heavy panting, continuous spreading of wings with wings more fully extended than in pattern IV, vertical bobbing of the tail and slight drooping of the body.

During a flight, the ambient air temperature inside the flight cage (T_A) was measured with a Narda Model 8011 RF Transparent Temperature Monitor. The ambient air temperature and relative humidity in the Rindge Avenue Microwave Irradiation Facility (RAMIF) was measured with a sling psychrometer immediately before every flight. It was assumed that ambient water vapor pressure in the flight cage (P_A) was equal to that in RAMIF.

4.8.3 Results and Discussion

The appearance of leg dropping and gaping responses and refusal to fly were observed in six budgerigars (Figures 4-39 to 4-44; Appendix A4.8-1). The leg-drop response was the first detectable sign of thermoregulatory behavior during flight. This response did appear at ambient temperatures as low as 25^{o} during both control and irradiated flights. The incidence of leg-dropping increased at higher ambient temperatures (Figure 4-39) and occurred at a higher frequency in flights involving microwave irradiation than in control flights. This behavior appeared in more than 90 percent of all irradiation flights at T_A's above 26 or 28^{o}C whereas this frequency of appearance in control flights was only observed at T_A's above 34^{o}C.

During flight the lowest temperature at which gaping was observed in irradiated birds was 26^{o}C and 28^{o}C during control flights (Figure 4-40). This response, i.e., gaping, occurred in more than 50 percent of the flights with irradiation at temperature above 28^{o}C, and control flights above 34^{o}C. In the one of four flights above 34^{o}C in which gaping was not observed, the bird ("-W") actually glided with its tail lodged between the rear wires of the cage and the bird glided rather than flew for 9 of the 10 minutes of the test.

Figure 4-39. Influence of Ambient Temperature on Leg-Dropping Response Induced by Microwave Irradiation (50 mW/cm^2) of Birds during Flight.

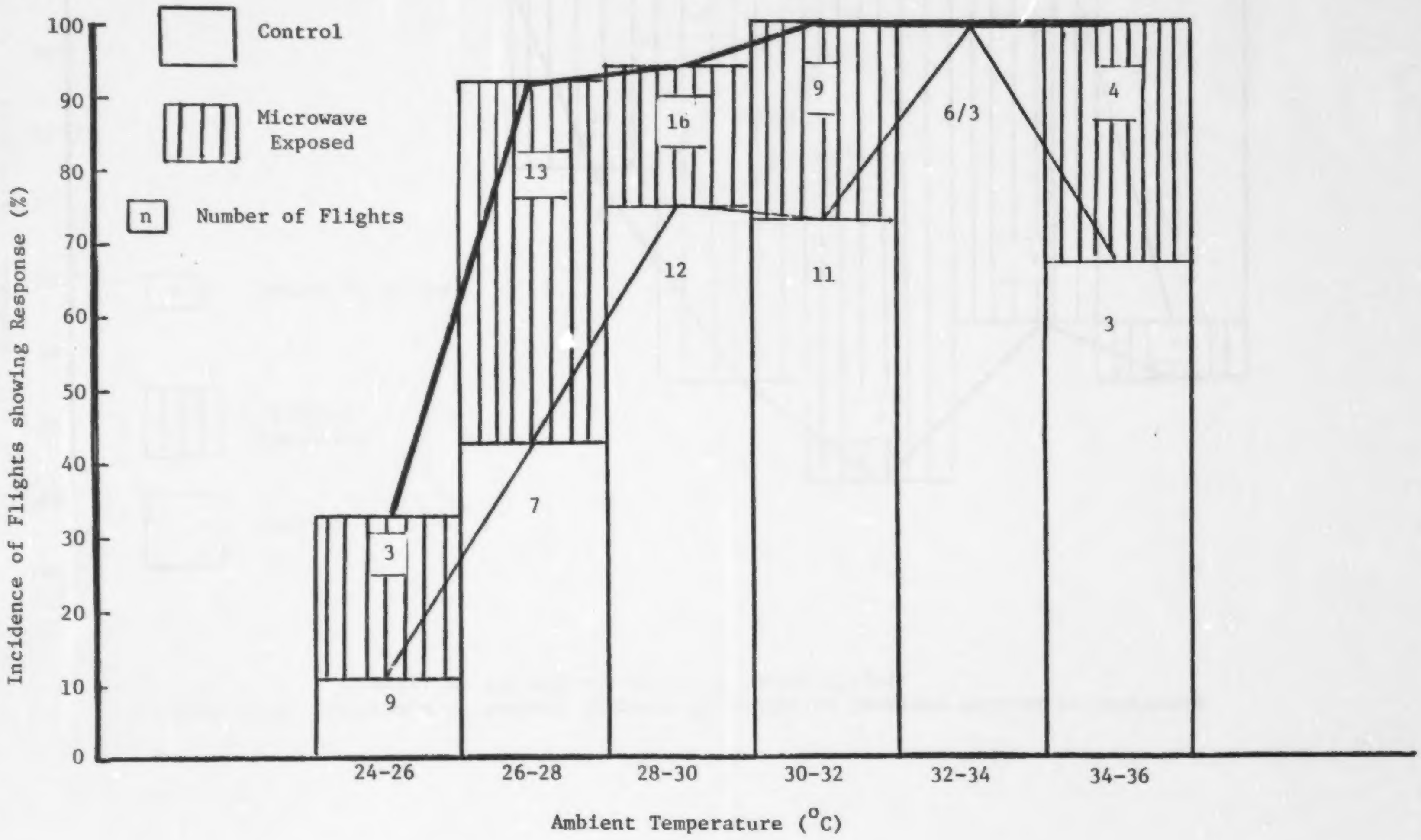


Figure 4-40. Influence of Ambient Temperature on Gaping Response Induced by Microwave Irradiation (50 mW/cm^2) of Birds during Flight.

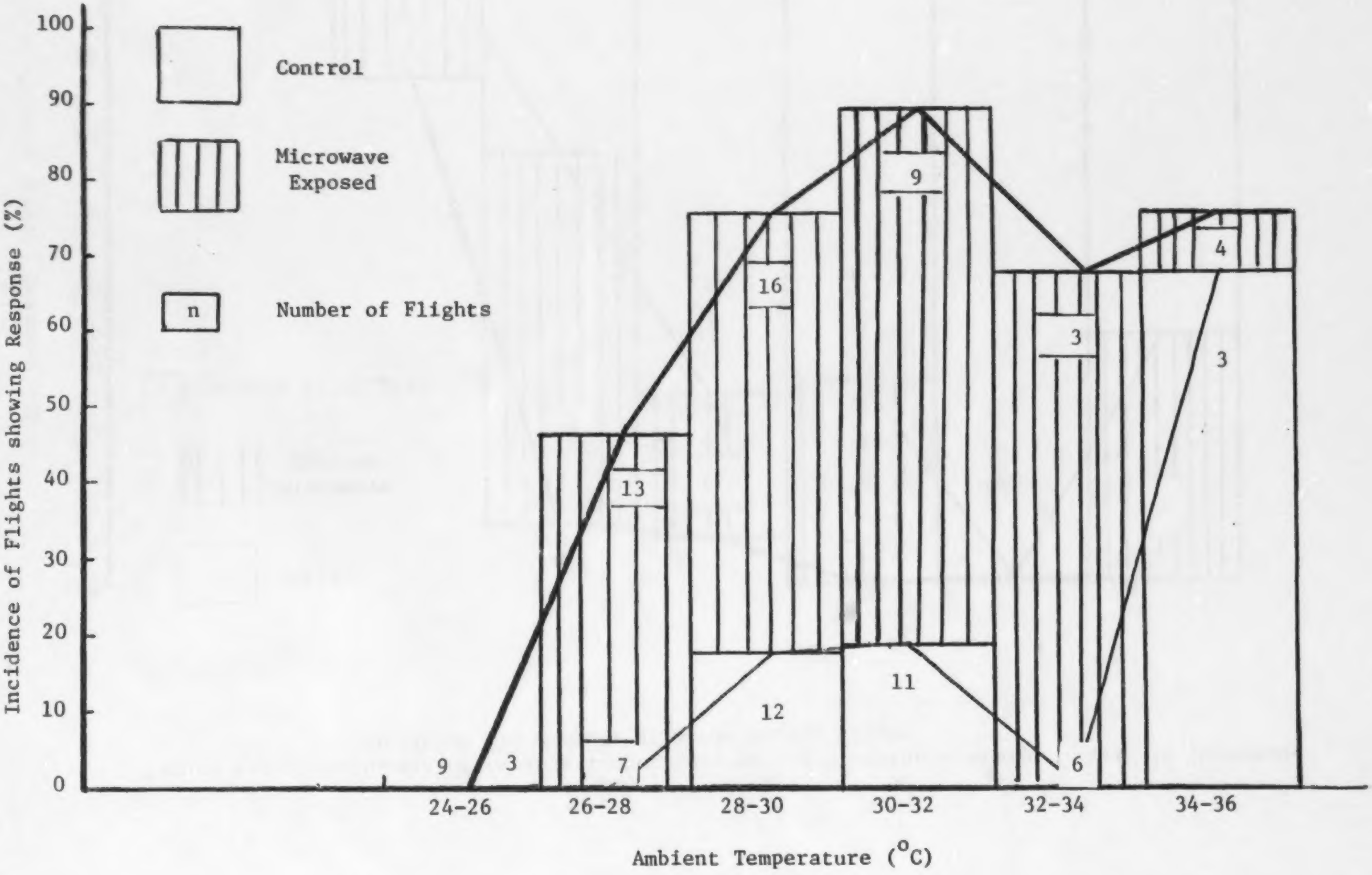


Figure 4-41. Influence of Ambient Temperature on Landing Response Induced by Microwave Irradiation of Birds During Flight

50 mW/cm^2

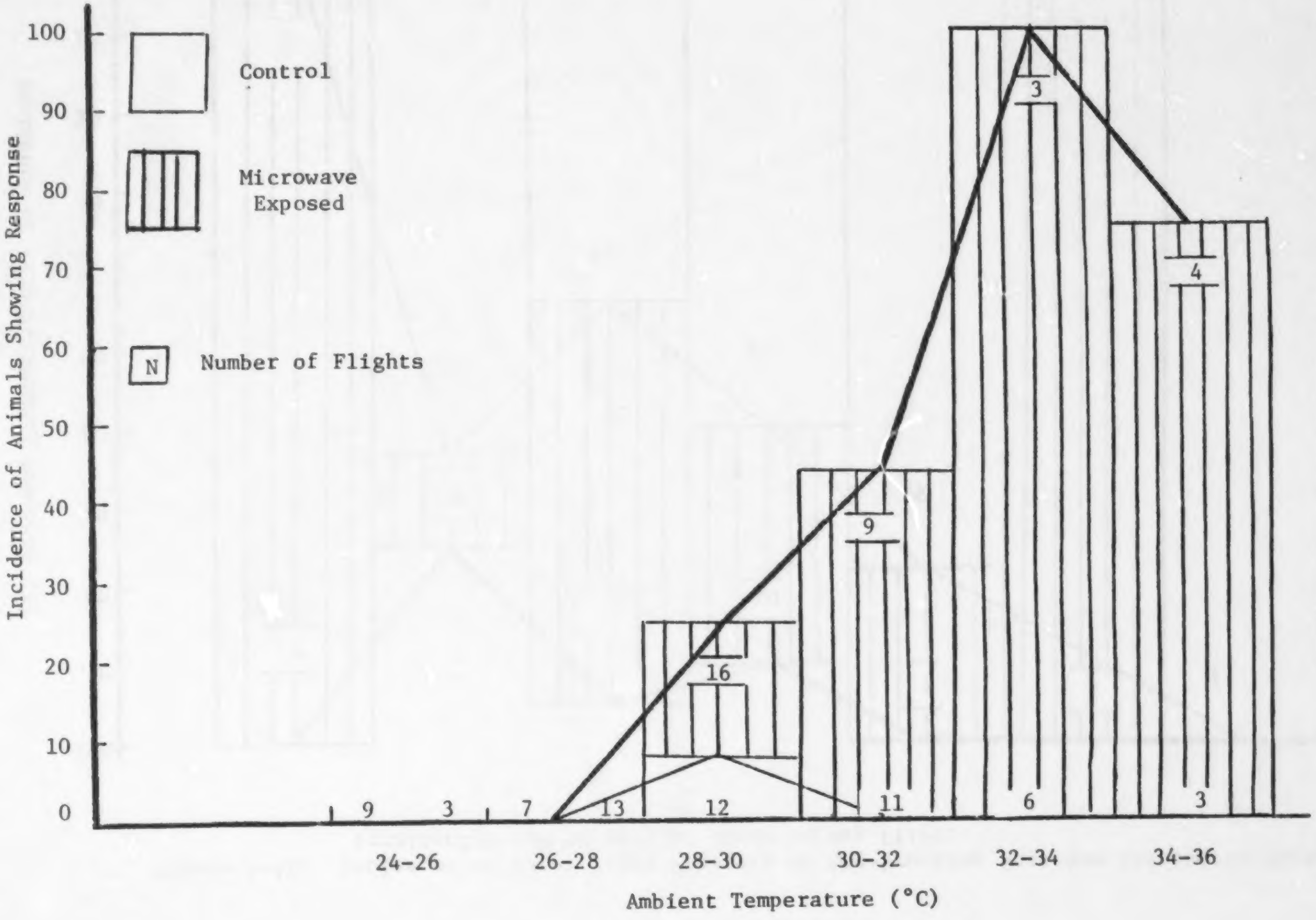


Figure 4-42. Influence of Water Vapor Pressure on Leg-Dropping Response Induced by Microwave Irradiation (50 mW/cm^2) of Birds during Flight.

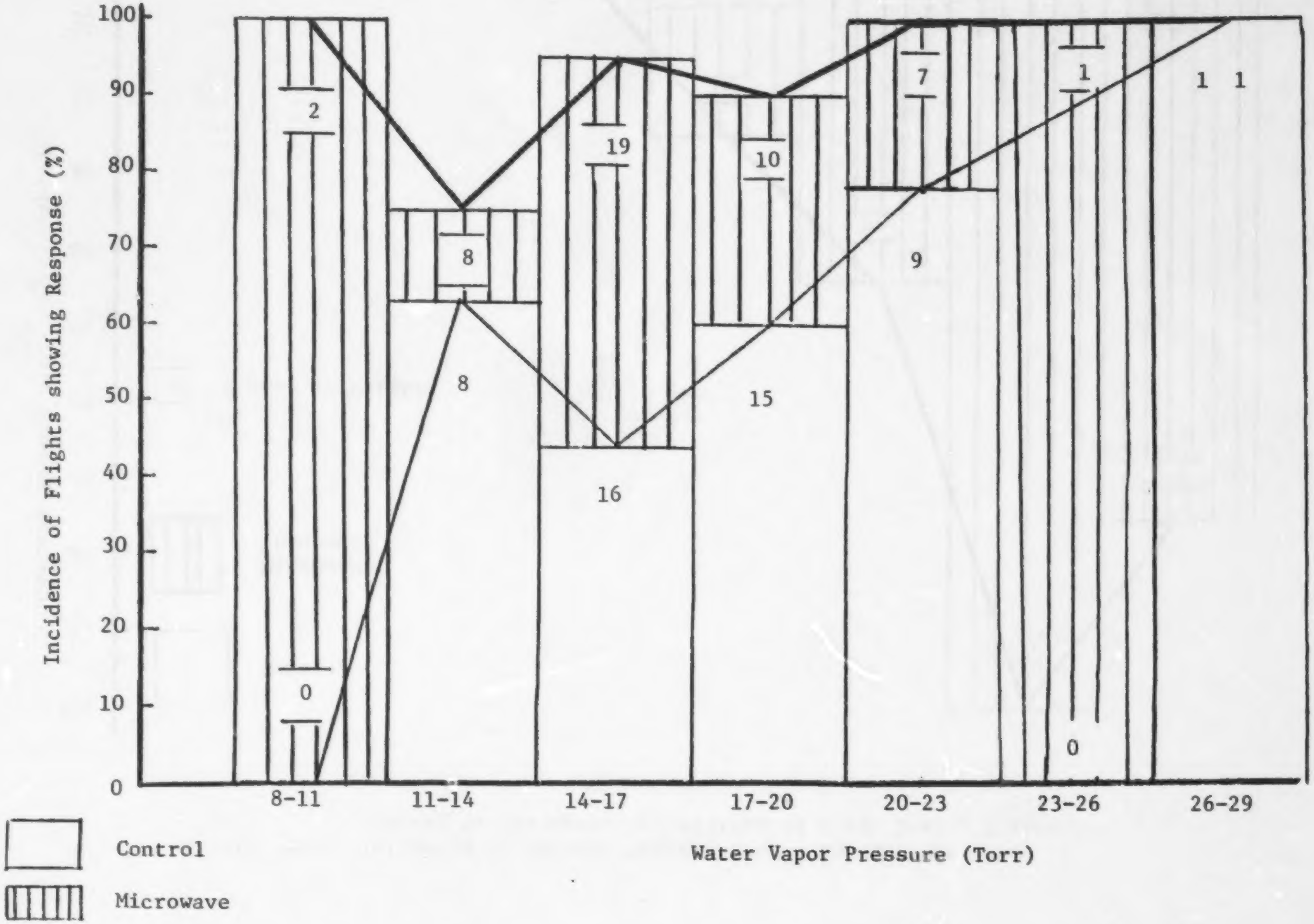


Figure 4-43. Influence of Water Vapor Pressure on Gaping Response Induced by Microwave Irradiation of Birds During Flight $50\ mW/cm^2$

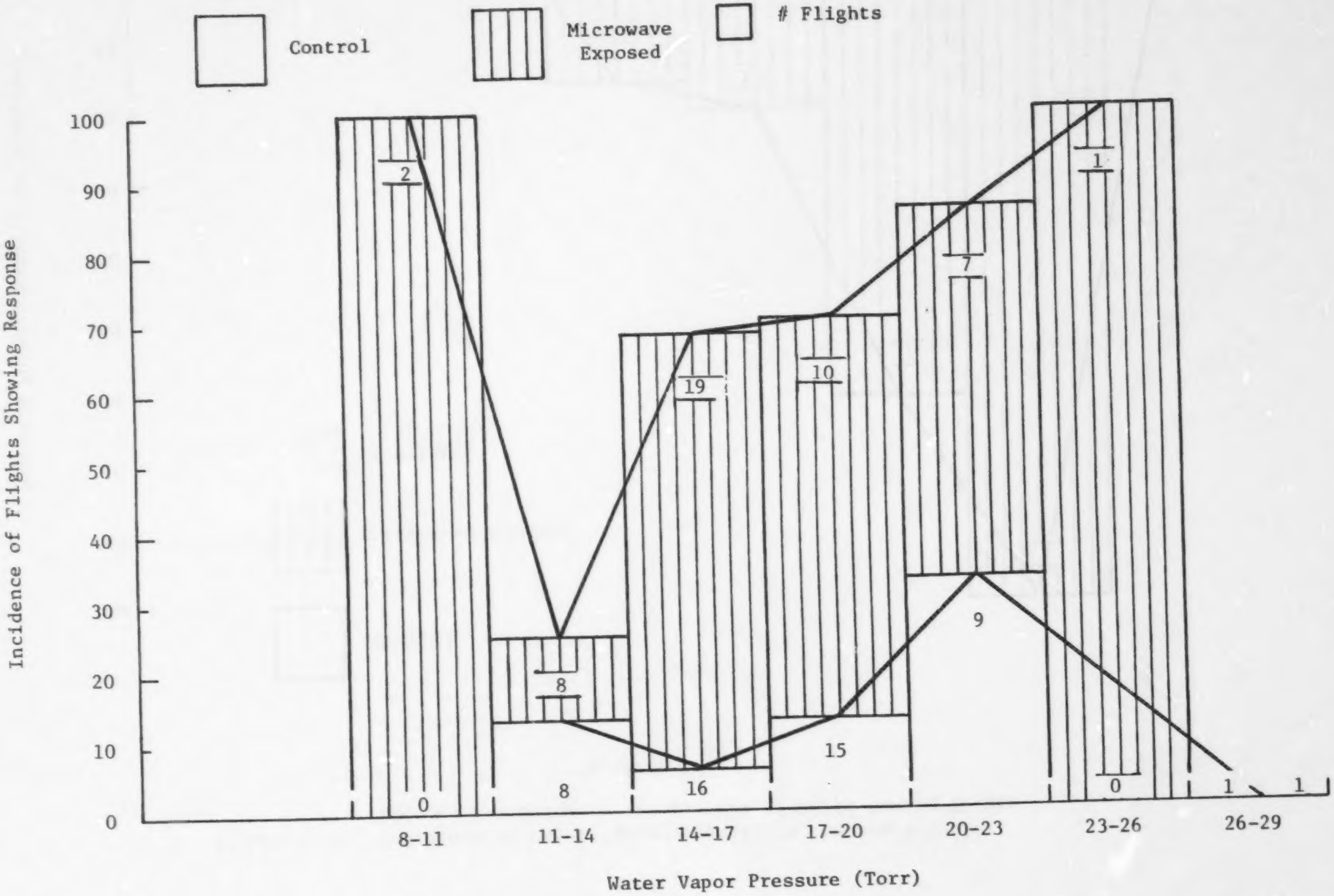
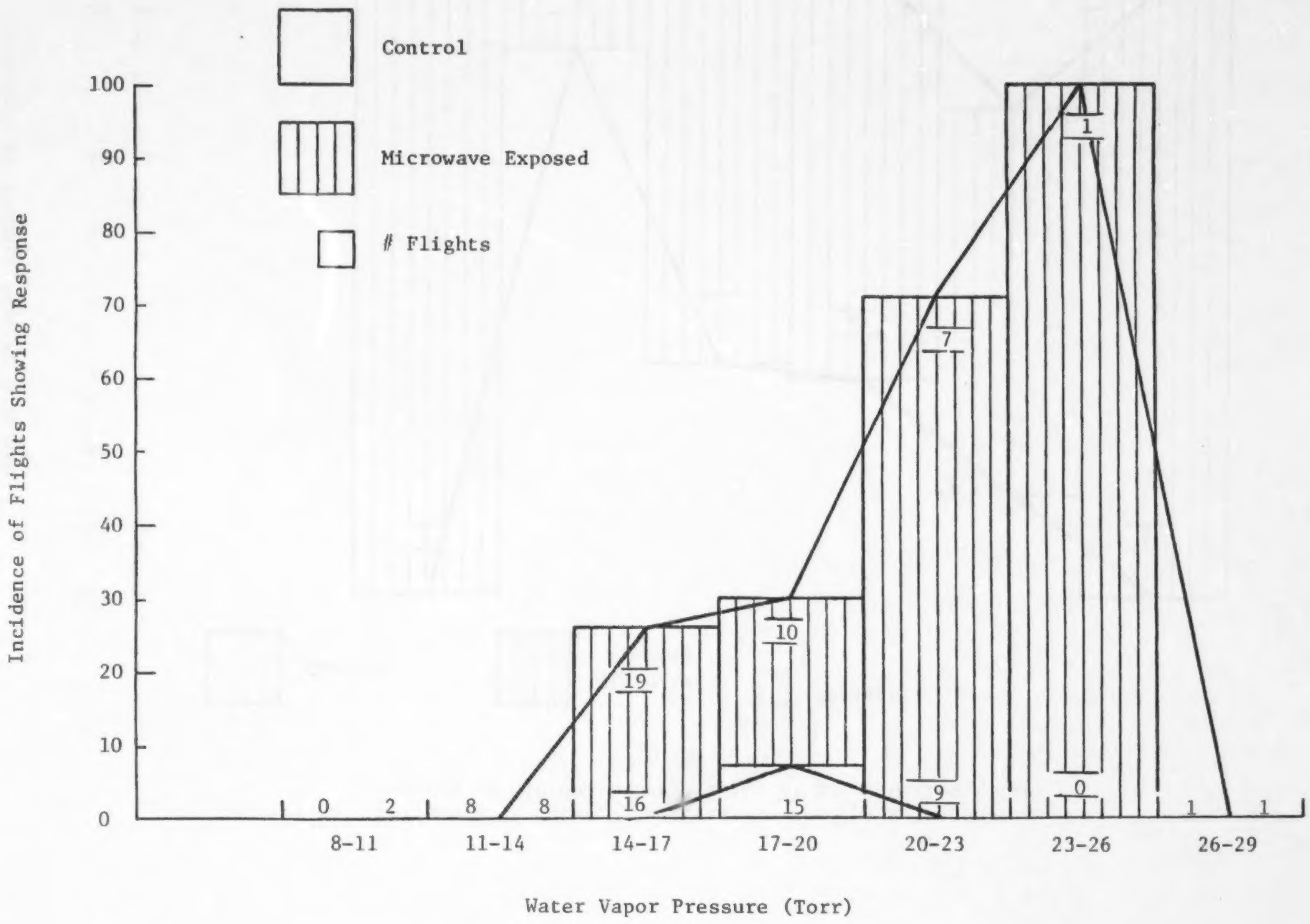


Figure 4-44. Influence of Water Vapor Pressure on Landing Behavior Induced by Microwave Irradiation of Birds During Flight

50 mW/cm^2



The frequency of flights during irradiation that ended prematurely (in less than 10 minutes) rose from zero at T_A's below 28°C to 100 percent at T_A's between 32 and 34°C (Figure 4-41). The flight above 34°C that lasted 10 minutes was by "-W", whose gliding behavior was described above. Forty-seven of 48 control flights at ambient temperatures between 24 and 36°C lasted for the maximum permitted duration of 10 minutes.

The leg-dropping response occurred at water vapor pressures above 11 Torr during control flights; the incidence of this response ranged between 60 and 80 percent at vapor pressures below 23 Torr (Figure 4-42). Too few control flights were conducted at vapor pressures above 23 Torr to permit analysis. With microwave irradiation the leg-dropping response occurred in greater than 74 percent of all flights. If the 100 percent incidence (2/2) at 8 to 11 Torr range is considered a poor estimate due to small sample size, then the frequency of appearance of this response increases from 75 percent in the 11-14 Torr range to 100 percent during microwave flights at P_A's above 20 Torr.

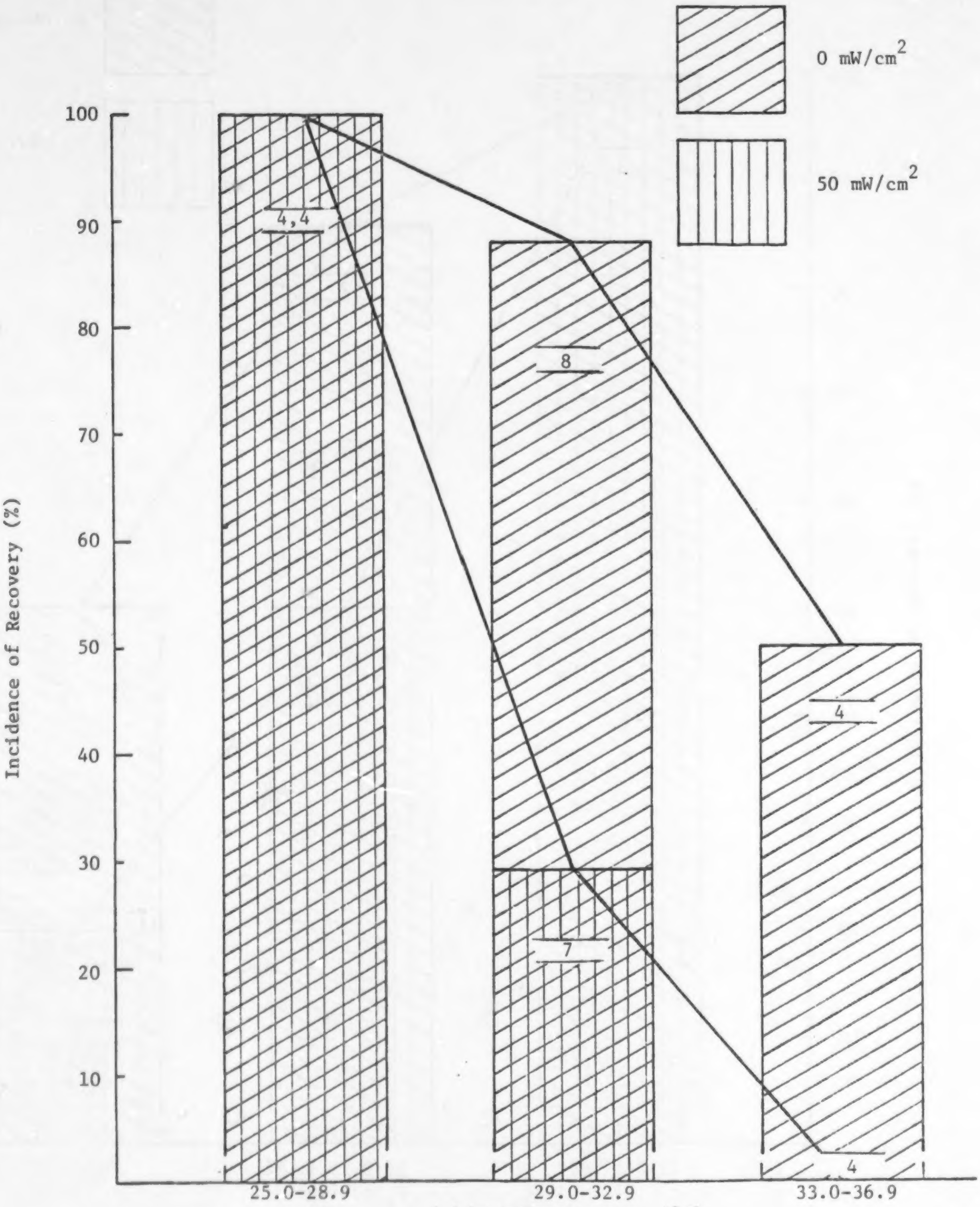
At P_A's between 11 and 23 Torr, the frequency of the gaping response rose from 25 to 86 percent of flights during irradiation and 13 to 33 percent of control flights (Figure 4-43). The frequency of the premature landing response rose from 0 to 71 percent when irradiated birds flew at vapor pressures ranging between 11 and 23 Torr whereas only 1 of 44 control flights conducted in this same range of vapor pressures ended prematurely (Figure 4-44). Sample sizes for a flight above 23 Torr were also too small to permit reliable estimates of endurance except to note that the irradiated bird "-W" was able to fly for 10 minutes at a water vapor pressure greater than 26 Torr.

All behavioral evidence of thermal stress disappeared within 10 minutes after flights were terminated for both irradiated and control birds when the ambient temperature was below 29°C (Figure 4-45). When ambient temperatures ranged between 29.0 and 32.9°C, budgerigars demonstrated complete recovery during a 10-minute period following 86 percent of control flights and 28 percent of radiation flights. At ambient temperatures within the 33-36.9°C range, birds did not completely recover from thermoregulatory stress in 10 minutes in 50 percent of the control and 100 percent of the microwave flights.

Behavioral evidence of thermal stress disappeared within 10 minutes after control and microwave flights were terminated when the ambient water vapor pressure was below 18 Torr (Figure 4-46). When ambient vapor pressures ranged betwen 18 and 20.9 Torr, 87 percent of control and 50 percent of irradiated budgerigars demonstrated complete recovery within 10 minutes following flights. At ambient vapor pressures greater than or equal to 21 Torr, birds did not completely recover from thermoregulatory stress within the 10-minute post-flight period in 50 percent of the control and 80 percent of the microwave flights.

The effect of ambient temperature on post-flight body temperature differed between control and microwave flights (Figure 4-47). At T_A's above 27°C, a linear relationship ($T_b = 31.56 + 0.41\ T_A$) existed

Figure 4-45. Influence of Ambient Temperature on Incidence of Budgerigars Recovering from Flight Within 10 min.*



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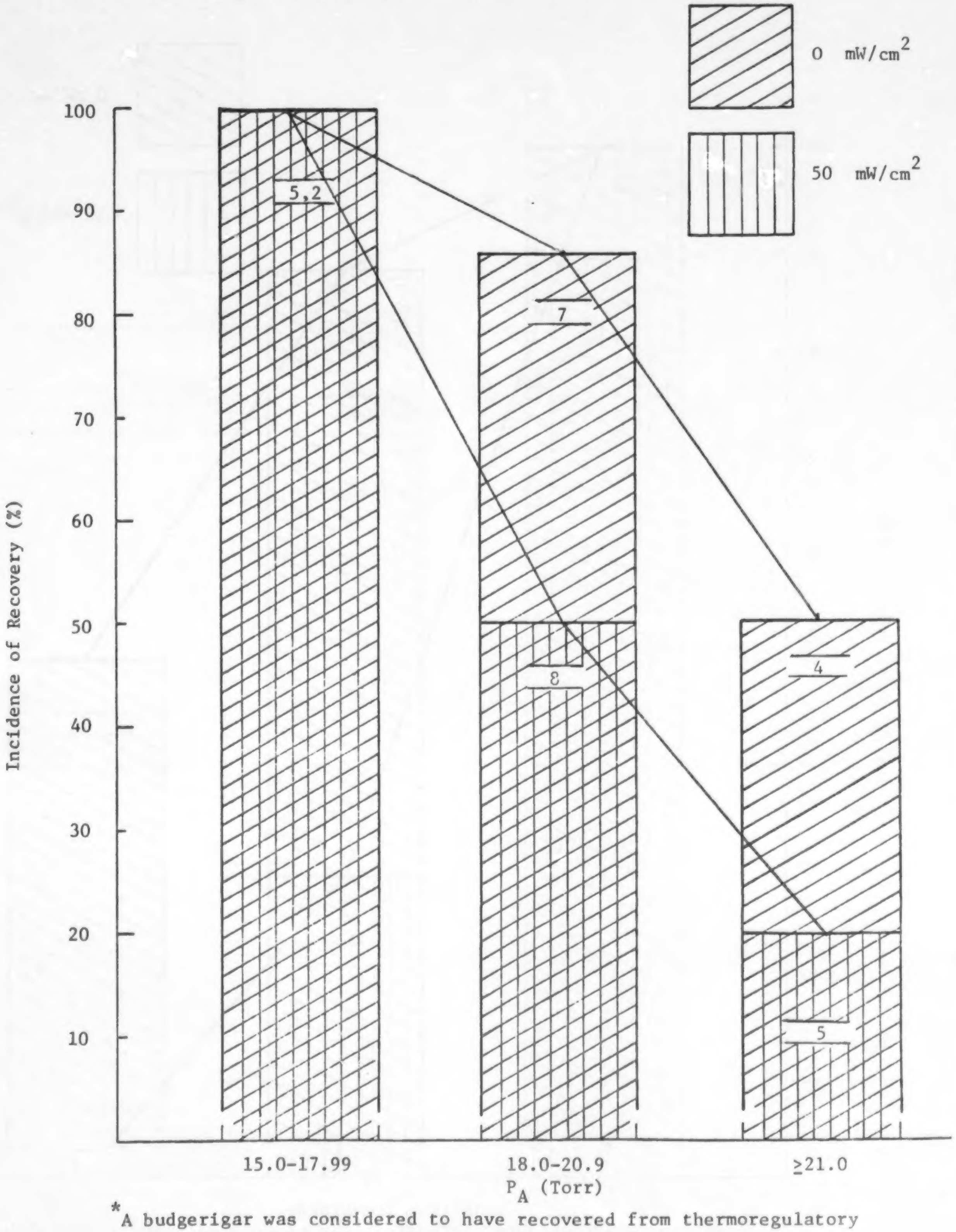
*A budgerigar was considered recovered from thermoregulatory stress induced by flight when it was observed to be in stress level 0.

Figure 4-46. Influence of Ambient Water Vapor Pressure (P_A) on Incidence of Budgerigars Recovering from Flight Within 10 min.*



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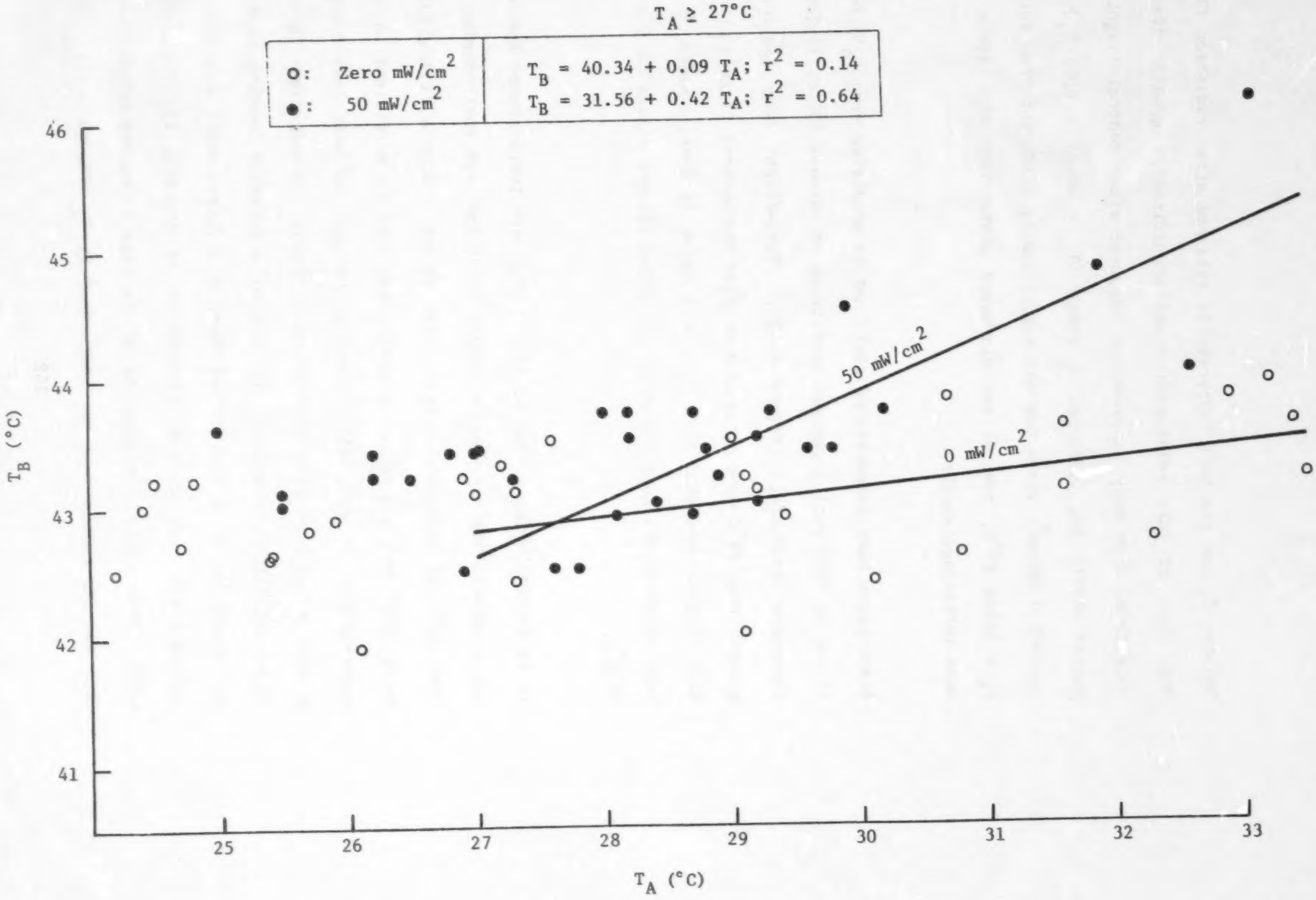
*A budgerigar was considered to have recovered from thermoregulatory stress induced by flight when at stress level 0.

Figure 4-47. Influence of Ambient Temperature (T_A) on Post-Flight Body Temperature (T_B) of Budgerigars Irradiated by Microwaves during Flight

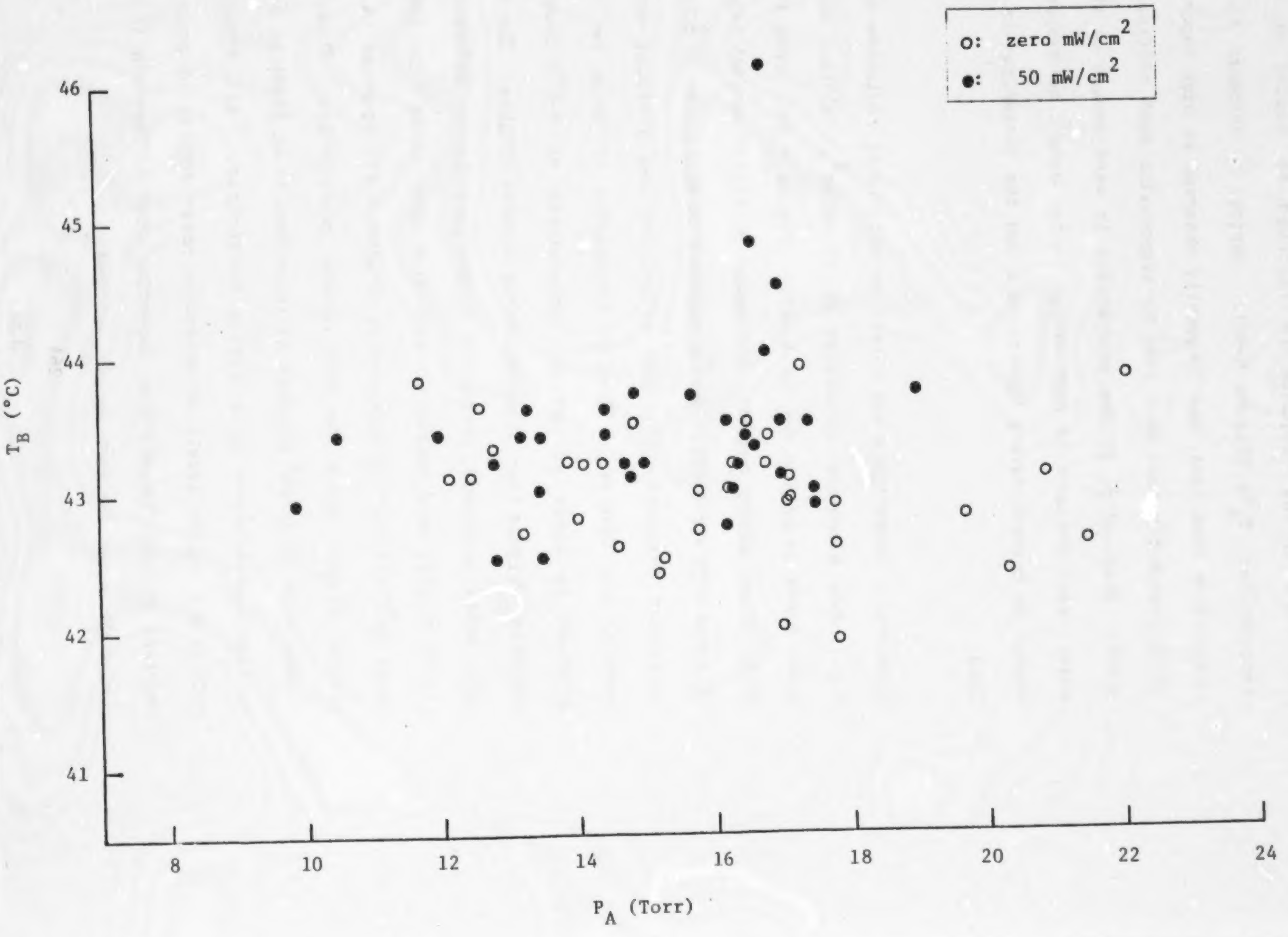


between T_A and the body temperatures measured after radiation flights. The slope of this relationship was significantly greater than that calculated from body temperatures measured after control flights conducted within the identical T_A range ($T_B = 40.34 + 0.09\ T_A$). The control 0 mW/cm^2) slope was not significantly different from zero. At T_A's below 27°C, control and microwave post-flight body temperatures were indistinguishable.

Post-flight body temperatures could not be predicted from P_A's between 11 and 22 Torr during control conditions or between 10 and 19 Torr for microwave irradiation (Figure 4-48). Post-flight body temperatures greater than 44°C were not measured after any control flights or microwave flights conducted when P_A's were below 16 Torr. Above 16 Torr, body temperatures measured after radiation flights ranged from 42.8 to 46.3°C.

It is difficult for a bird to fly at high air temperatures because of the metabolic heat production needed for flight and environmental heat load combined to produce severe heat stress. When a flying bird is faced with such a combined thermal load that is sufficient to induce hyperthermia, it must either increase its rate of heat loss enough to prevent a net heat gain or else cease flying. A budgerigar forced to remain in flight because of the lack of a suitable landing site in a hot desert (or on an electrified floor of a flight cage) will initially increase its rate of heat dissipation by dropping its legs (Figure 4-39). Presumably, the dropping of the legs increases convective heat loss and its presence is not influenced by P_A (Figure 4-42). Often,

Figure 4-48. Influence of Ambient Water Vapor Pressure (P_A) on Post-Flight Body Temperature (T_B) of Budgerigars Irradiated by Microwaves during Flight



the leg-dropping response is followed by gaping at high body temperatures, T_A's (Figure 4-40). Gaping, a response to increased evaporative heat loss, was frequently observed at high vapor pressures which presumably made heat loss by evaporation most difficult (Figure 4-43). Eventually, if the environment is warm enough or the ambient water vapor pressure is high enough, water cannot be evaporated fast enough to prevent severe hyperthermia and the budgerigar is forced to land.

Apparently, budgerigars can detect an additional radiative heat load; e.g., when microwave irradiated at 50 mW/cm^2. Without microwaves, these birds could fly for 10 minutes (Figure 4-41), even though leg dropping and gaping behavior did appear at higher ambient temperatures (Figures 4-39 and 4-40). During exposure to microwaves at 50 mW/cm^2 an increased frequency of birds exhibiting leg dropping and gaping behavior was observed. Similar frequencies of these two responses occurred in birds at ambient temperatures of 4-6°C lower during radiation flights than occurred during control flights. The frequency with which microwave irradiated budgerigars landed before their 10 minute flights were completed, rose from zero at 28°C to 100 percent above 32°C (if "-W" is discounted) (Figure 4-41) compared to only one control flight, where the bird landed prematurely. These results suggest that 50 mW/cm^2 exposure is equivalent to at least an 8°C higher ambient temperature to a flying budgerigar. All birds should effectively equate levels of microwave power density to proportionate increase in body temperature, depending upon differences in specific absorption rates for each species of bird.

The essentially linear relationship between premature landing of irradiated birds with vapor pressure (P_A) (Figure 4-44) was probably the result of the increasing difficulty with which the budgerigars were able to lose microwave induced heat by evaporation of water at the higher P_A's. Ambient water vapor pressures greater than 20 Torr usually occurred when ambient temperatures were above 30°C (see Appendix A4.8). Under such conditions, the additional heat load from absorption of microwaves was particularly stressful.

After microwave flights at T_A's above 29°C and P_A's above 18 Torr, budgerigars usually could not recover from thermoregulatory stress within 10 minutes, whereas after control flights, birds would usually recover within that time period (Figures 4-45 and 4-46). Birds under thermoregulatory stress produced by flights through a microwave field would presumably be incapable of vital activities such as feeding, grooming and escape from predators for a period of time. The length of this incapacitation would depend on the availability of perches where a stressed bird could cool, e.g., relatively low T_A's and high wind speeds.

When T_A is above 30°C, irradiation by 50 mW/cm^2 microwaves can induce T_B's above 44°C in flying budgerigars. It can be expected that a bird would be forced to land rather than continue to fly under such adverse environmental conditions. If a flying budgerigar is exposed to a microwave power density lower than 50 mW/cm^2, the T_A necessary to achieve a 44°C T_B would be higher.

5.0 DOSIMETRY AND THERMAL MODELING

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5.1 THERMAL MODELING OF BIRDS EXPOSED TO MICROWAVE IRRADIATION

5.1.1 Introduction

The irradiation experiments performed with live birds provided information on thermal responses (modified behavior and cloacal temperature rise) as a function of microwave exposure power density. These tests were conducted under essentially a single set of controlled laboratory conditions. However, there are a number of factors in the natural environment, such as ambient temperature and humidity, solar radiation, and wind speed, which would significantly influence a thermal response. In order to predict the effects of these parameters, an analytical heat-transfer model of birds subjected to microwave radiation was developed.

The principal objective of the modeling effort was to extrapolate results obtained under laboratory and field conditions to estimate the response for parametric variations in environmental conditions. The model assumes steady-state conditions (long-term exposure) in order to provide conservative estimates of response to different radiation levels. The model was calibrated using biothermal data from the published literature and the results of the irradiation experiments conducted in the Arthur D. Little laboratories. It was then applied to a number of different bird species to predict maximum tolerable radiation levels for ranges of environmental conditions typical of what would be encountered in the field. The theoretical basis for the model and the results obtained in its implementation are presented in the following sections.

5.1.2 Derivation of Thermal Model

5.1.2.1 Basic Energy Balance

The sketch given in Figure 5-1 shows the various components of energy flow for a bird subjected to microwave radiation. For the steady-state condition, the bird is in thermal balance and dissipates heat at a rate equal to the sum of the rates of heat absorption and internal (metabolic) heat production. In terms of the components shown in Figure 5-1, this energy budget can be expressed as follows:

$$\dot{Q}_c'' + \dot{Q}_R'' + \dot{E}'' = \left[\frac{A_c}{A_b}\alpha_S\right]\phi_S + \left[\mathrm{SAR}\,\frac{m_b}{A_b}\right]\phi_M + \dot{M}'' \qquad (1)$$

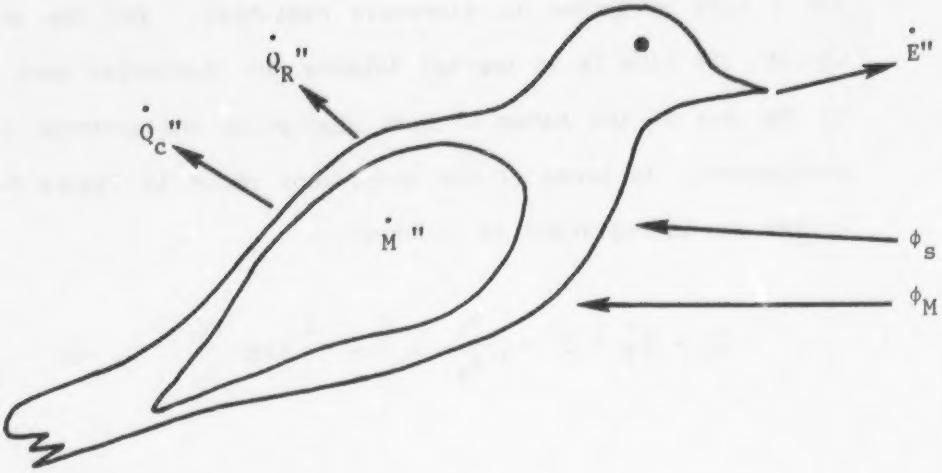
where:

$\dot{Q}_c''$ ≡ Rate of heat loss per unit surface area by convection, $\mathrm{mW/cm^2}$

$\dot{Q}_R''$ ≡ Rate of heat loss per unit surface area by radiation, $\mathrm{mW/cm^2}$

$\dot{E}''$ ≡ Rate of heat loss per unit surface area by evaporation, $\mathrm{mW/cm^2}$

ϕ_s ≡ Incident solar radiation flux, $\mathrm{mW/cm^2}$



$\dot{M}''$ ≡ Internal Metabolic Heat Generation, mW/cm^2 surface area

$\dot{E}''$ ≡ Evaporative Heat Loss, mW/cm^2 surface area

$\dot{Q}''_R$ ≡ Radiated Heat Loss, mW/cm^2 surface area

$\dot{Q}''_c$ ≡ Convective Heat Loss, mW/cm^2 surface area

ϕ_s ≡ Incident Solar Flux, mW/cm^2 cross sectional area

ϕ_M ≡ Incident Microwave Flux, mW/cm^2 cross sectional area

Figure 5-1. Components of Energy Balance for Bird

ϕ_M ≡ Incident microwave radiation flux, mW/cm^2

$\dot{M}''$ ≡ Rate of metabolic heat production per unit surface area, mW/cm^2

A_c ≡ Cross sectional area of bird normal to solar flux, cm^2

A_b ≡ Surface area of bird, cm^2

m_b ≡ Mass of bird

S.A.R. ≡ Specific absorption ratio (power absorbed per unit weight divided by incident microwave flux), $(mW/g)/(mW/cm^2)$

α_S ≡ Infrared absorptivity of bird

5.1.2.2 Governing Equations

Equation 1 can be rearranged to obtain the expression for ϕ_M:

$$\phi_M = \frac{(A_b/m_b)}{SAR}\left[\dot{Q}_e'' + (\dot{E} - \dot{M}'')\right] \qquad (2)$$

where, for convenience, we have defined $\dot{Q}_e''$ as the net rate of heat loss to the environment:

$$\dot{Q}''_e \equiv \dot{Q}''_c + \dot{Q}''_R - \left[\frac{A_c}{A_b} \alpha_S \right] \phi_S \tag{3}$$

Following standard procedures found in the literature (e.g., Robinson 1977) for treatment of the convective and radiative components, we can express $\dot{Q}''_e$ as:

$$\dot{Q}''_e = \frac{C_a}{r_T} (T_b - T_e) \tag{4}$$

where r_T is the total thermal resistance, T_b is the internal body temperature of the bird, T_e is the "blackbody equivalent" temperature of the environment, and C_a is the volumetric heat capacity of air at standard conditions. The latter is simply a conversion constant allowing the resistance to be expressed in units of time per unit length which is the conventional approach in biothermal calculations.

The total resistance to heat transfer is the sum of two resistances in series:

$$r_T = r_b + r_e \tag{5}$$

The quantity r_b is the internal body resistance of the bird associated with subcutaneous tissue and feathers. The term r_e is the external resistance which is a function of environmental conditions. This is the sum of two parallel resistances:

$$\frac{1}{r_e} = \frac{1}{r_r} + \frac{1}{r_a} \tag{6}$$

In this expression, r_r is a fictitious "radiative" resistance resulting from the manner in which the radiation heat-transfer term is treated numerically. This resistance is defined as:

$$r_r = \frac{C_a}{4\epsilon\sigma T_a^3} \tag{7}$$

where ϵ is the emissivity of the bird's outer surface, σ is the Stefan-Boltzmann constant, and T_a is the ambient air temperature.

The resistance r_a is that associated with the air boundary layer. Empirical expressions from the literature (Robinson et al 1977) were used in evaluating r_a for different conditions. In the case where there is no wind, r_a is the free convection resistance and can be estimated as:

$$r_a = 820 \left[\frac{d}{T_s - T_a} \right]^{1/4} \text{ sec/m} \tag{8}$$

where d is the characteristic dimension of the bird in meters and T_s is the surface temperature in $^{\circ}$K. For the case where a wind is blowing at U m/sec, r_a is given by the following correlation for forced convection:

$$r_a = 310 \sqrt{d/U} \text{ sec/m} \tag{9}$$

The blackbody equivalent temperature T_e is defined as the equilibrium value which a model animal with no internal heat production would reach when exposed to the environment of the actual bird. The expression defining T_e is obtained from an energy balance as follows:

$$T_e \equiv T_a + \frac{\dot{S}''_A}{(C_a/r_e)} \tag{10}$$

where the term $\dot{S}''_A$ is simply the rate of absorption per unit surface area of the incident solar radiation:

$$\dot{S}''_A = \frac{A_c}{A_b} \alpha_S \phi_S \tag{11}$$

5.1.2.3 Solution Procedure

The value of ϕ_M given by Equation (2) can be interpreted as the maximum level of microwave radiation at which a bird can maintain thermal equilibrium with the environment at a given metabolic state. This value is dependent on the environmental conditions (such as ambient temperature, wind velocity, etc.) through their effect on $\dot{Q}''_e$. In addition, Q_M is a function of the biothermal parameters $\dot{E}''$, $\dot{M}''$, T_b and r_b. These parameters vary not only with bird species, but also with thermoregulatory behavior.

Different values would correspond to the onset of different responses to thermal stress such as the elevation of body temperature, gaping, panting, and eventually death. Since these parameters cannot be predicted analytically, it is necessary to rely on empirical data in order to implement the model for any given species.

5.1.3 Review of Literature Data on Biothermal Parameters

Various investigators (Hinds 1973 and Weathers 1975) have conducted experiments with live birds in which the parameters of interest were measured for wide ranges of environmental conditions. In general, the tests consisted of placing individual birds in metabolic chambers maintained at constant temperature and ventilated with a low flow of dry CO_2-free air. Rates of oxygen consumption, CO_2 production and evaporative water loss were determined by continuously measuring the concentrations of O_2, CO_2, and H_2O vapor entering and leaving the chamber. Cloacal temperatures were measured at the start and conclusion of each test period. The results of these tests provide data on the variations of biothermal parameters with environmental load imposed on the bird.

The typical results obtained by these investigators are illustrated by the data plotted in Figure 5-2 for Monk Parakeets (Weathers 1975). The variations of $\dot{M}''$, $\dot{E}''$ and T_b with ambient temperature represent smoothed curves which provide the best fit to the experimental data. The heat loss to the environment by convection and radiation ($\dot{Q}_e''$) was calculated from the corresponding curves for $\dot{M}''$ and $\dot{E}''$.

At ambient temperatures below about 25°C, the bird is able to maintain a

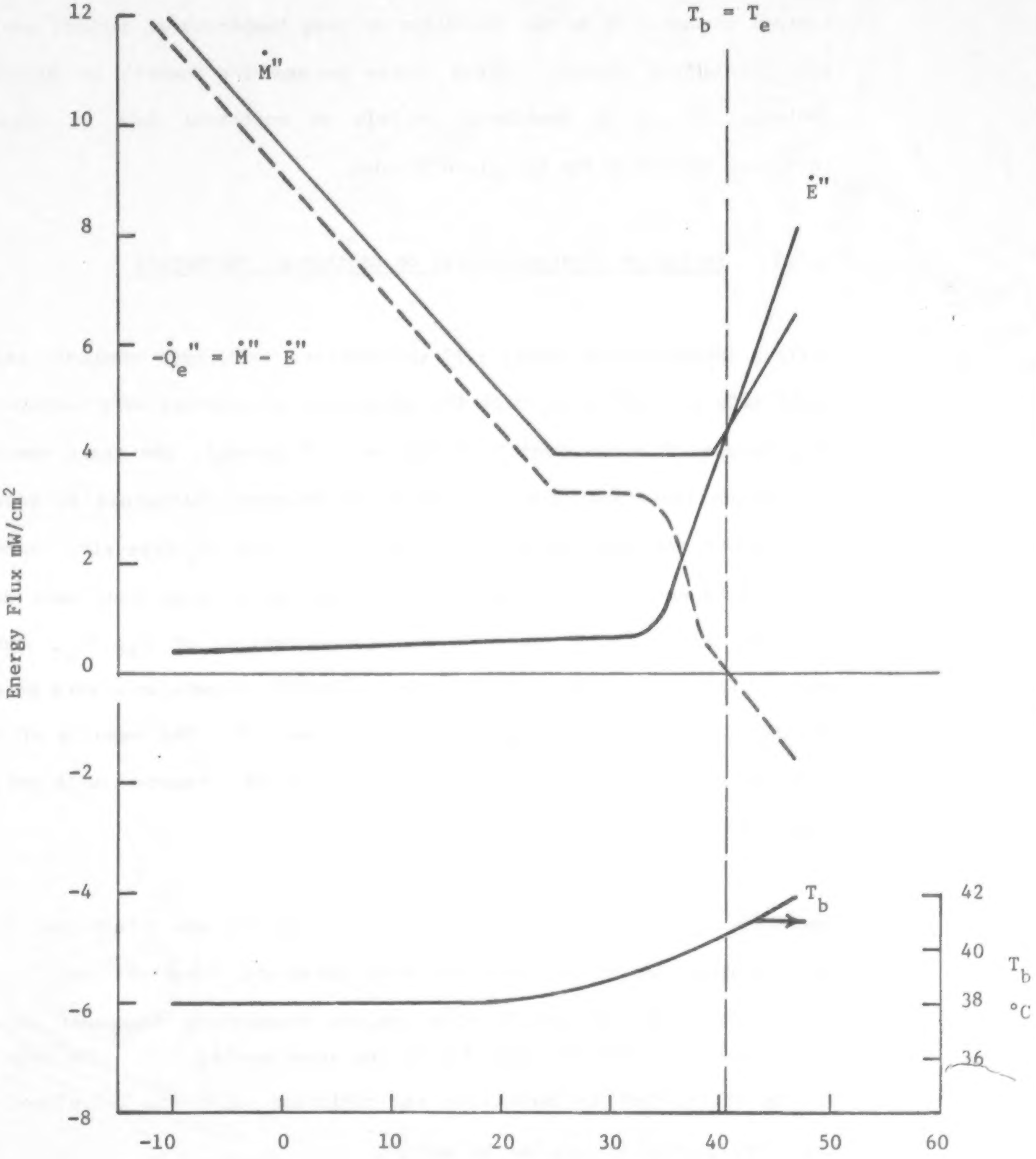


Figure 5-2. Effect of Ambient Temperature (T_a) on Energy Budget for Monk Parakeets (Reference 3)

fairly constant body temperature by adjusting its metabolic rate. Over the temperature range 25-35°C, the metabolic rate is at its minimum value and other means of achieving thermal equilibrium with the environment are required. The principal method in this range of temperature consists of reducing the thermal resistance of the body by thermoregulatory behavior such as wing spreading and feather sleeking. As the ambient temperature rises above the critical value of around 35°C, evaporative cooling becomes the predominant mode of heat loss. This is indicated by the observed sharp rise in $\dot{E}''$ which apparently marks the onset of an increased respiration rate corresponding to panting. The rise in $\dot{E}''$ is accompanied by increases in metabolic rate ($\dot{M}''$) and body temperature (T_b). All three of these parameters continue to rise to maximum values at the highest ambient temperature tested of around 47°C. Since the tests were terminated at conditions which appeared to be close to lethal, we assume that these extremes of $\dot{E}''$, $\dot{M}''$, and T_b correspond to the maximum tolerable values which this particular species of bird can maintain without succumbing to heat prostration.

The data presented in Figure 5-2 can be used to compute the thermal body resistance of the bird. The results are plotted in Figure 5-3 which shows the variation in r_b with temperature. As can be seen, the resistance remains fairly constant over a wide range of ambient temperatures. At conditions where the ambient temperature is approaching the body temperature, the thermal resistance drops dramatically and exhibits a rather sharp minimum. This variation in resistance represents the effect of the thermoregulatory response of the body in attempting to maximize heat rejection under conditions of high thermal stress.

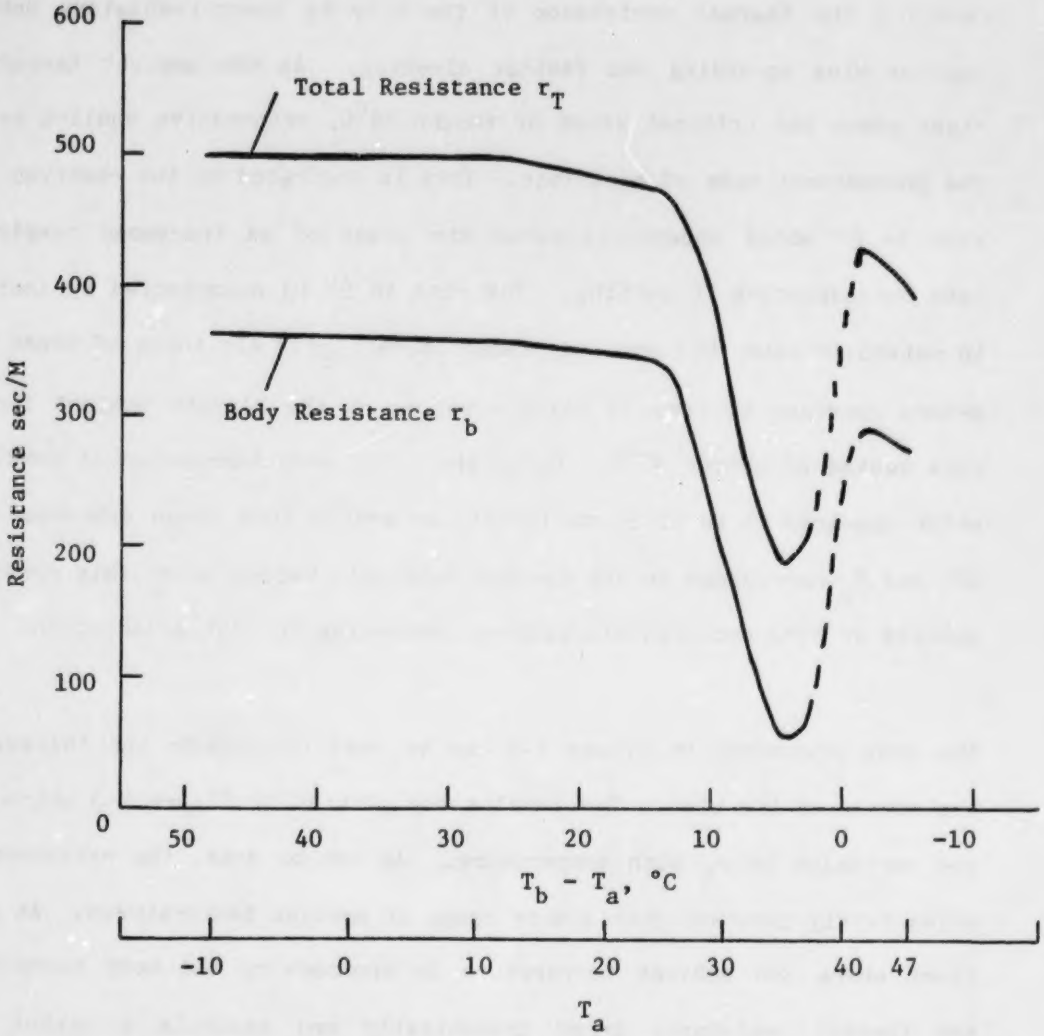


Figure 5-3. Variation of Body Resistance with Difference Between Body Temperature and Ambient for Monk Parakeets (Reference 3).

The variations of $\dot{M}''$, $\dot{E}''$, T_b, and r_b discussed above are representative of the results obtained by other investigators. The absolute values of these parameters, however, are dependent on the physical characteristics of the bird species being considered. Figure 5-4 summarizes the available literature data for three species.

The higher values of r_b correspond to the body resistance under normal conditions (that is, no heat stress). The broken curve drawn through these points represents an empirical correlation developed by Harreid and Kessel (1967). This correlation apppears to fit the data quite well. The lower set of data points for r_b represents the minimum values observed which appear to be independent of size for the three species considered here.

The data on body temperature elevation above normal represent the maximum values measured by each investigator. The results seem to indicate a slight increase with decreasing body weight. In view of the somewhat subjective nature of these tests, it is probably reasonable to assume that the maximum tolerable temperature elevation is roughly constant.

The plotted data for $\dot{E}''_{min}$ and $\dot{M}''_{min}$ correspond to the values measured at the point where the metabolic rate has been reduced to its minimum. The results indicate that both of these quantities are relatively independent of bird size. The curves labeled $\dot{E}''_{max}$ and $\dot{M}''_{max}$ show the correponding values measured at the highest ambient temperature tested by each investigator.* As noted previously, we assume that these provide an indication of the maximum sub-lethal values threshold of these parameters. From the results presented in Figure 5-4, it is apparent that the relevant biothermal parameters correlate fairly well with body weight. Consequently, in considering any particular species, its characteristic body mass can be used in conjunction with the data plotted in Figure 5-4 to estimate the appropriate values of the required biothermal parameters.

5.1.4 Calibration Model

Implementation of the developed heat-transfer model for the purpose of predicting the thermal response to microwave radiation requires information on the fraction of the incident flux which is absorbed by the body. In order to provide this information, a series of irradiation tests was conducted with a number of dead birds of differing weight. Each test consisted of placing a dead bird in an insulated box, exposing it to a constant known flux of microwave radiation, and monitoring its internal temperature rise with time. The test data were used to compute the specific absorption ratio (S.A.R.) for each sample bird. The results obtained are summarized

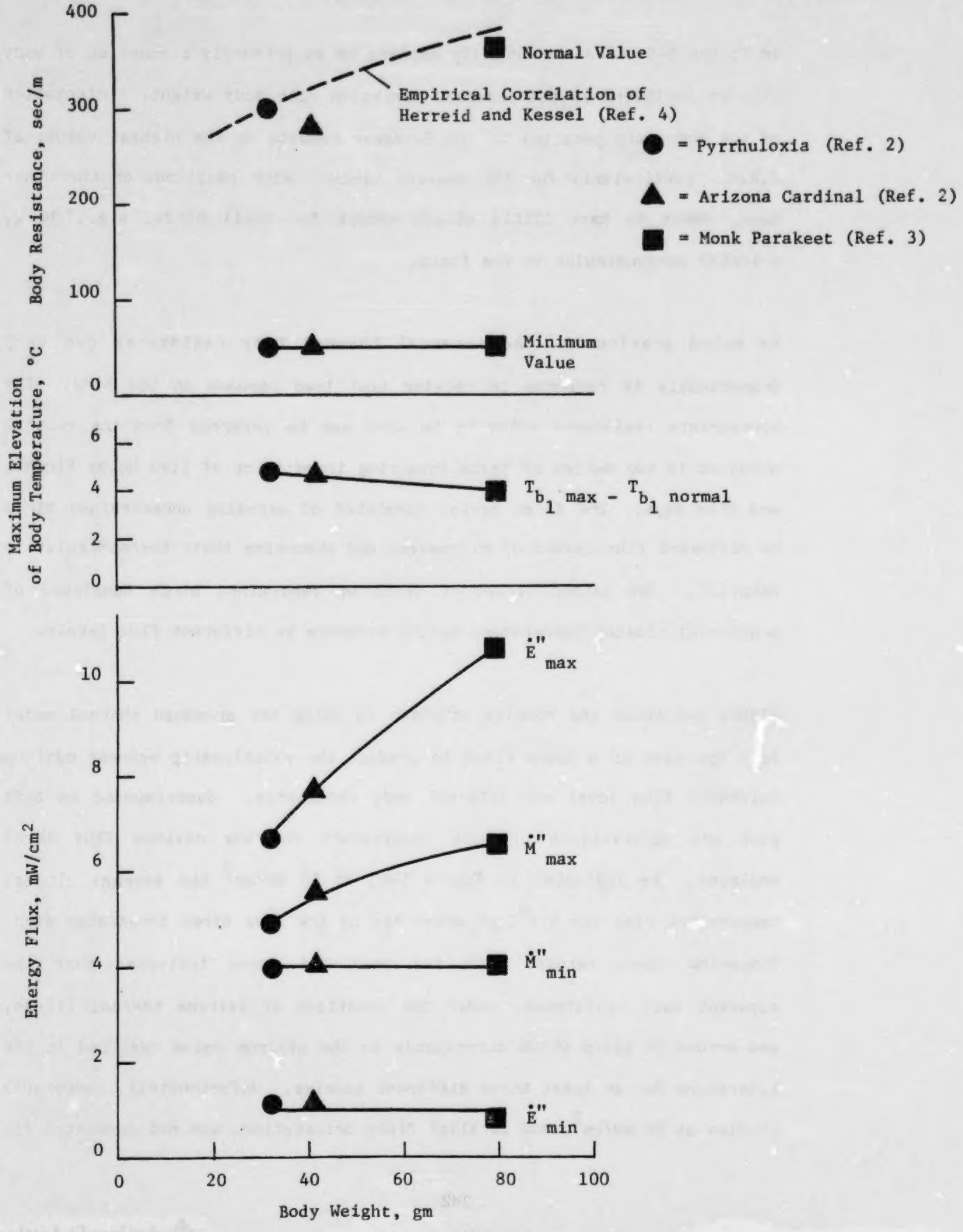
---

*In order to correct for differences in humidity, the values of $\dot{E}''$ have been corrected to zero air humidity assuming:

$$\dot{E}'' \alpha (\omega_{b,sat} - \omega_a)$$

where $\omega_{b,sat}$ is the absolute humidity corresponding to saturated conditions at the measured body temperature and ω_a is the absolute humidity of the air in the test chamber.

Figure 5-4. Variation of Heat Rejection Ability with Body Weight

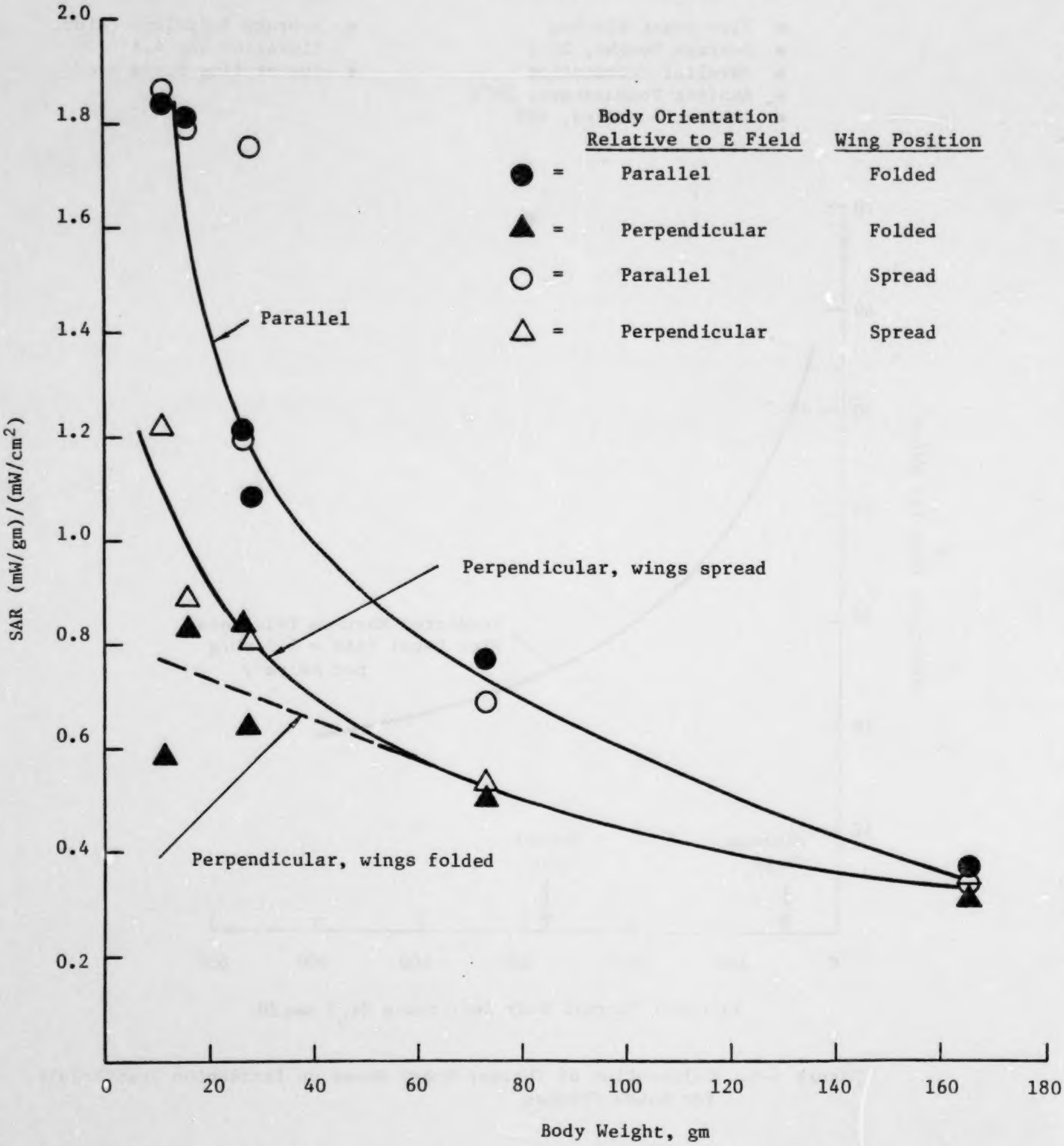


in Figure 5-5. The absorptivity appears to be primarily a function of body size as indicated by the observed variation with body weight. Orientation of the body axis parallel to the E-vector results in the highest values of S.A.R., particularly for the smaller birds. Wing position, on the other hand, seems to have little effect except for small birds, e.g., 30 g, oriented perpendicular to the field.

As noted previously, the internal thermal body resistance can vary dramatically in response to varying heat load imposed on the bird. The appropriate resistance value to be used can be inferred from the results obtained in two series of tests involving irradiation of live House Finches and Blue Jays. The first series consisted of exposing unrestrained birds to different flux levels of microwaves and observing their thermoregulatory behavior. The second series of tests on restrained birds consisted of monitoring cloacal temperature during exposure to different flux levels.

Figure 5-6 shows the results obtained in using the proposed thermal model for the case of a House Finch to predict the relationship between maximum tolerable flux level and internal body resistance. Superimposed on this plot are observations of body temperature for the maximum flux level employed. As indicated in Figure 5-6, at 50 mW/cm^2 the average cloacal temperature rise was 4.4°C at which two of the five birds irradiated died. Comparing these results with the predicted curve indicates that the apparent body resistance, under the condition of extreme thermal stress, was around 50 sec/m which corresponds to the minimum value reported in the literature for at least three different species. Unfortunately, comparable studies at 50 mW/cm^2, and parallel field orientation, was not conducted for

Figure 5-5 Experimentally Determined Variation of Absorptivity with Body Weight, Field Orientation, and Wing Position



Test Conditions

- Five House Finches
- Average Weight, 23 g
- Parallel Orientation
- Ambient Temperature, 24°C
- Ambient Humidity, 38%

Results

- Average Body Temperature Elevation was 4.4°C
- Two of five birds died

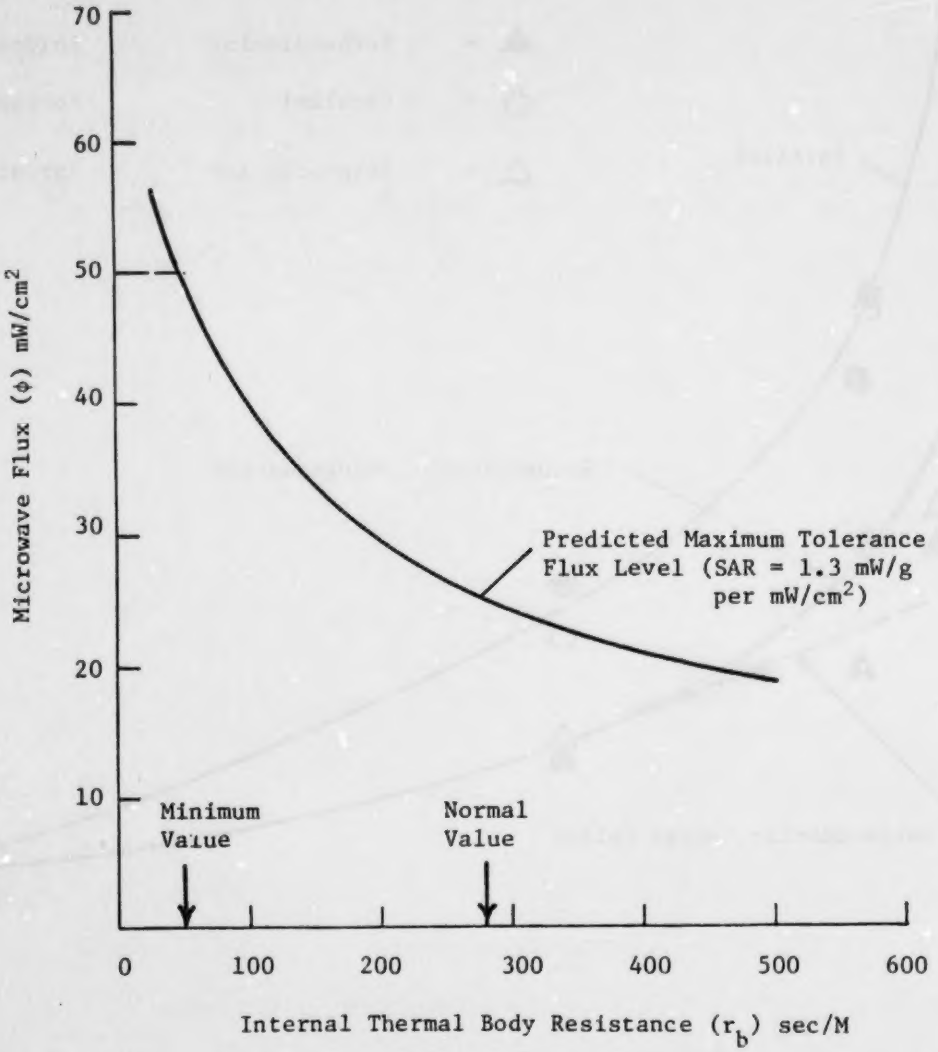


Figure 5-6. Calibration of Thermal Model Based on Irradation Test Results for House Finches

Blue Jays. Based on the available amount of information, we estimate that the minimum 50 sec/m value of body resistance is an appropriate value to be used in evaluating the maximum tolerable microwave flux. Although additional irradiation data are unavailable, this assumption appears to be consistent with results reported in the literature for the general case of exposure to extreme thermal load.

5.1.5 Predicted Thermal Response for Ranges of Environmental Conditions

The developed thermal model was used to calculate a series of parametric estimates of the threshold values of microwave flux corresponding to the two following different sets of conditions:

1. The onset of thermoregulatory behavior is assumed to begin at the point where the metabolic rate has been reduced to the minimum value.

2. Imminent death from hyperthermia is assumed to occur when the body temperature and panting rate have reached the maximum sub-lethal values.

The calculations were performed for two sample species, House Finches and Blue Jays, over the ranges of ambient temperature, humidity, solar radiation and wind speed listed in Table 5-0. Values are representative of those that might be encountered in the natural environment, e.g., SPS.

The results of the parameteric analysis are plotted in Figures 5-7, 5-8 and

Table 5-0

Scope of Parametric Calculations

Parameter	Baseline Value	Range
Ambient Temperature (T_a) °C	20	0 - 50
Ambient Relative Humidity (ω_a) %	50	0 - 100
Absorption of Solar Radiation (S''_A) mW/cm^2	15	0 - 30(1)
Apparent Wind Speed (U) mph(4)	10(2)	2.5(3) - 30

Notes:

1. The maximum value of S''_A was calculated using the method described by Campbell (1977) for the case of dark plumage, clear air, and direct sunlight.
2. The annual mean values of windspeed for the United States are in the range 5-16 mph (Ruffner 1981).
3. Except for controlled laboratory conditions, wind speed is never zero and rarely falls below half the annual mean value (ASHRAE 1978).
4. Apparent wind speed is the speed of the wind relative to the bird.

Figure 5-7. Predicted Effects of Ambient Temperature and Humidity on Threshold Flux Levels

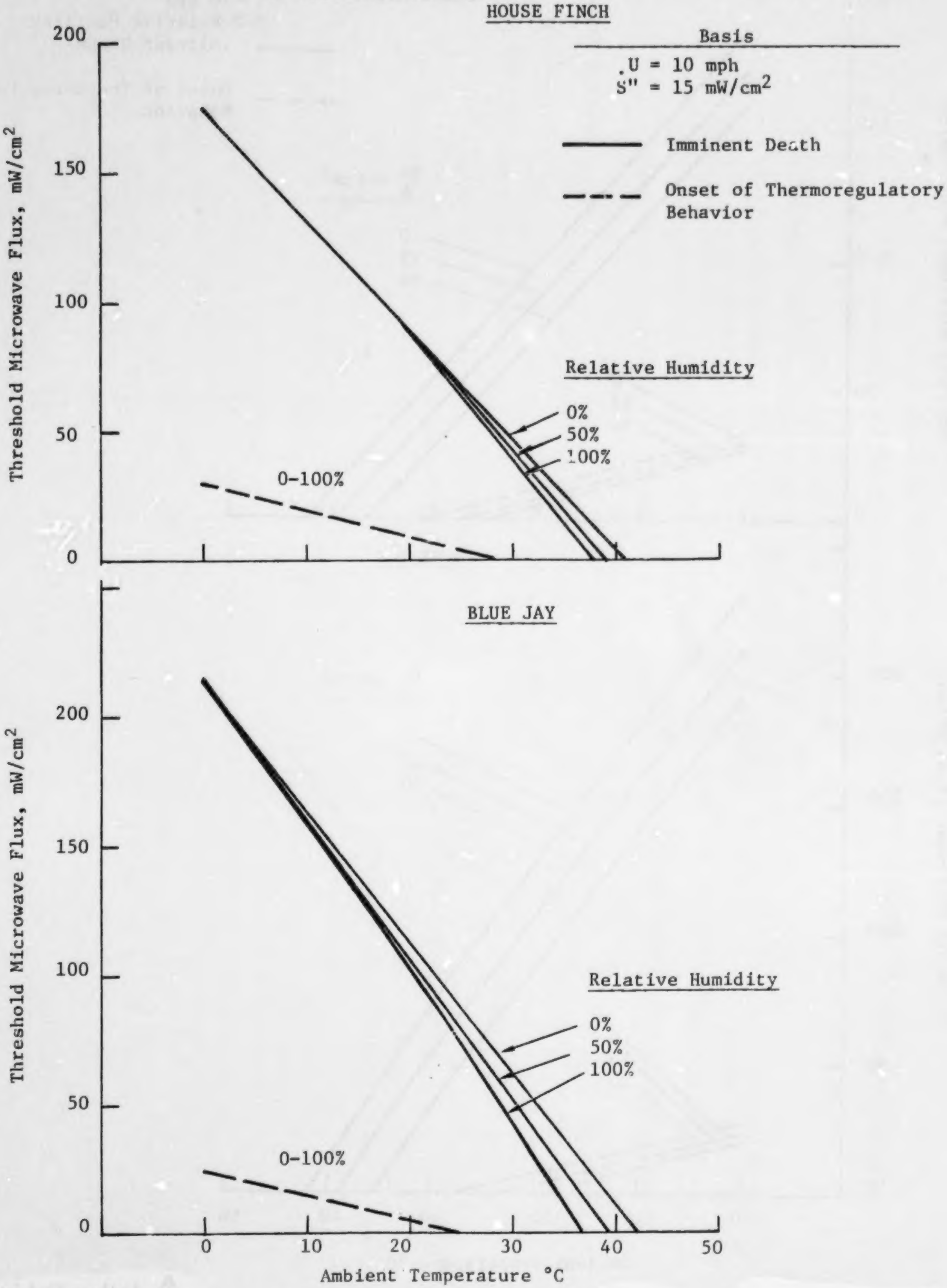
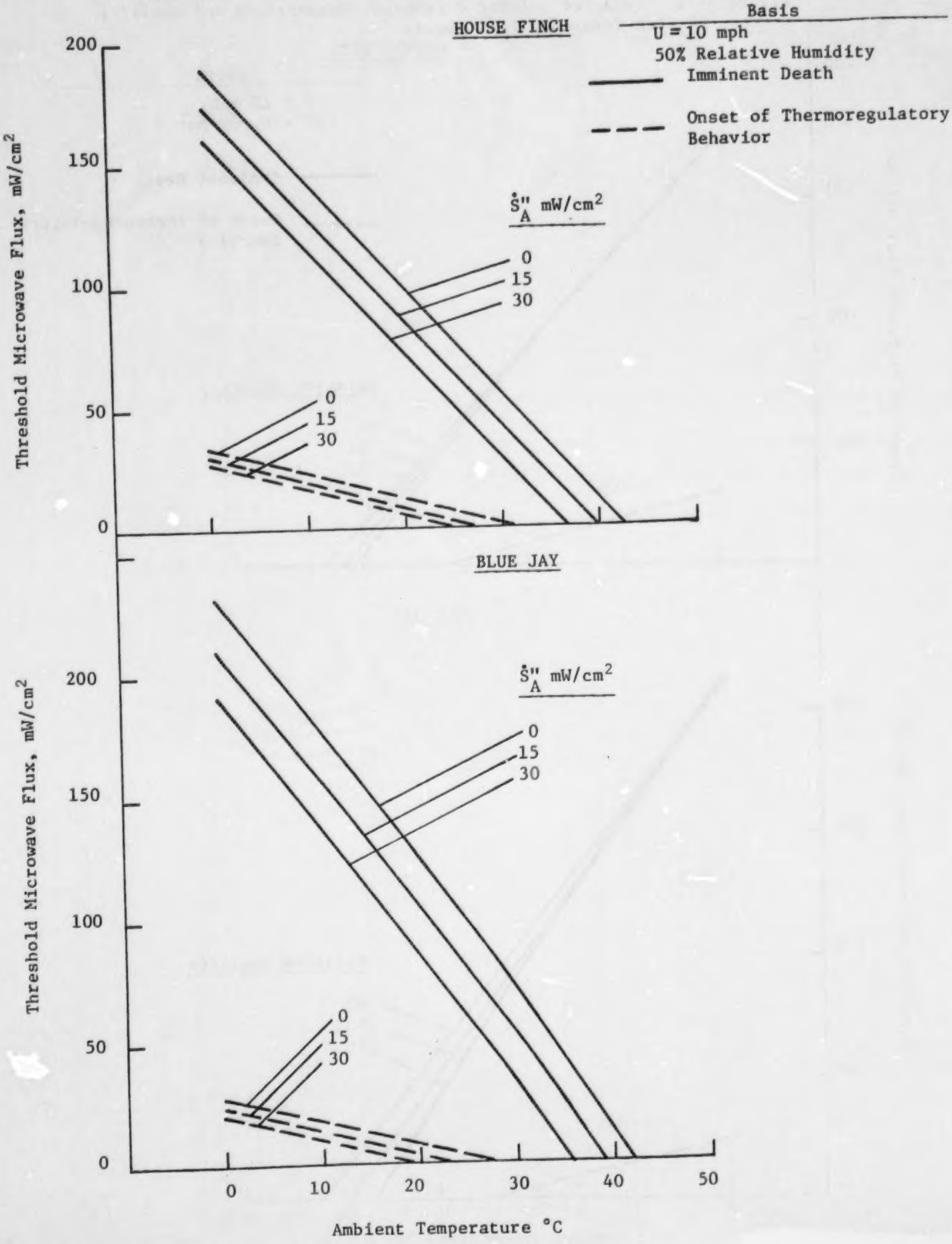


Figure 5-8. Predicted Effect of Solar Radiation on Threshold Flux Levels



5-9 and show the predicted effects of ambient temperature for different values of humdiity, solar radiation, and wind speed. On the basis of these results, the following conclusions can be drawn:

- The Blue Jay, which is the larger of the two species, appears to be somewhat more tolerant to microwave radiation than the House Finch.

- Ambient temperature has the greatest effect on threshold to microwave flux levels. For most ambient conditions, this effect is essentially linear.

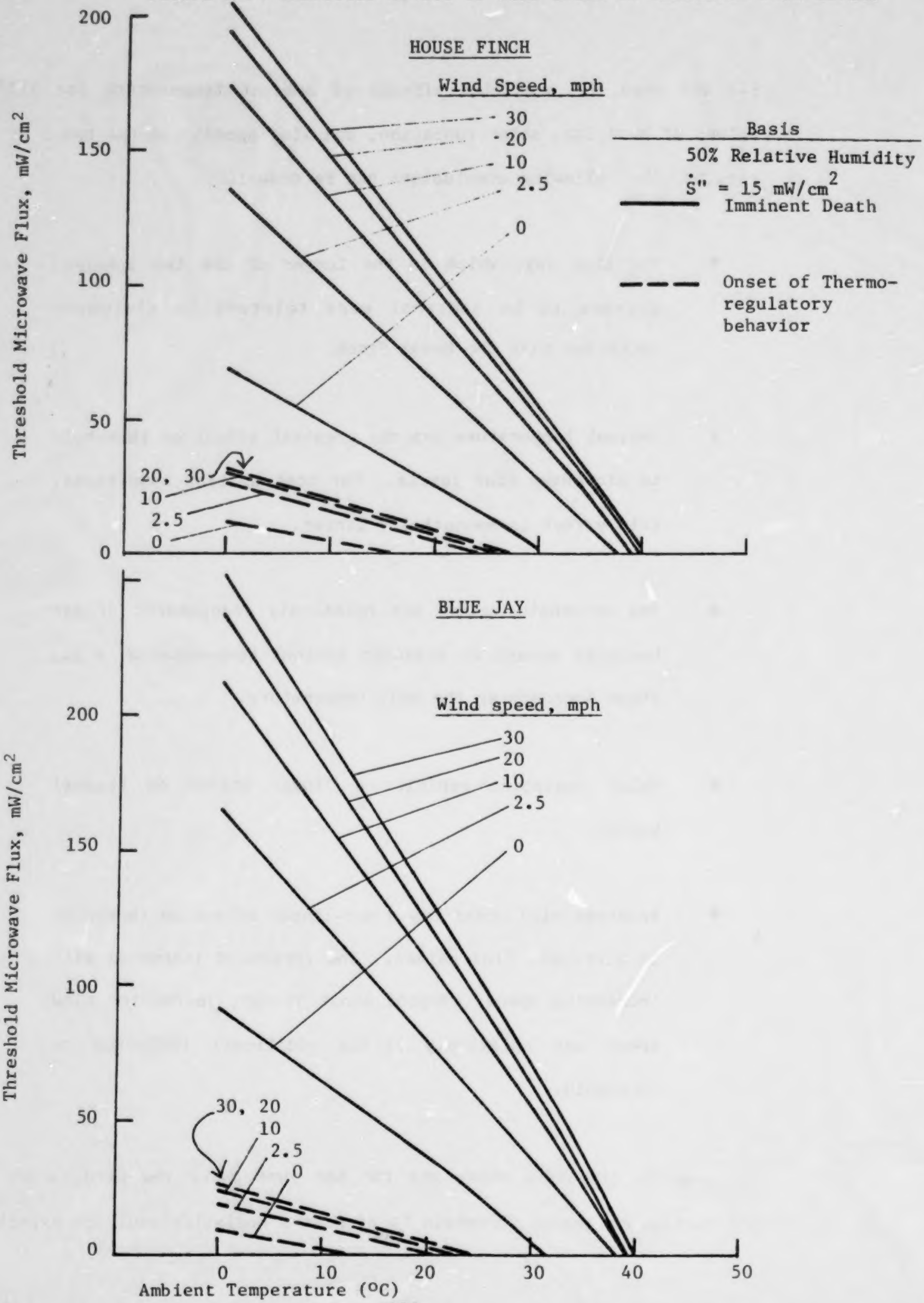
- The threshold values are relatively independent of air humidity except at elevated ambient temperatures, e.g., those approaching the body temperature.

- Solar radiation exhibits a linear effect on thermal burden.

- Apparent wind speed has a non-linear effect on threshold to microwave flux values. The threshold increases with increasing speed. Beyond about 30 mph, increasing wind speed has relatively little additional influence on threshold.

The results discussed above are for the case where the bird is at rest. The maximum tolerated threshold to microwave radiation would be expected to

FIGURE 5-9. PREDICTED EFFECT OF WIND SPEED ON THRESHOLD FLUX LEVELS

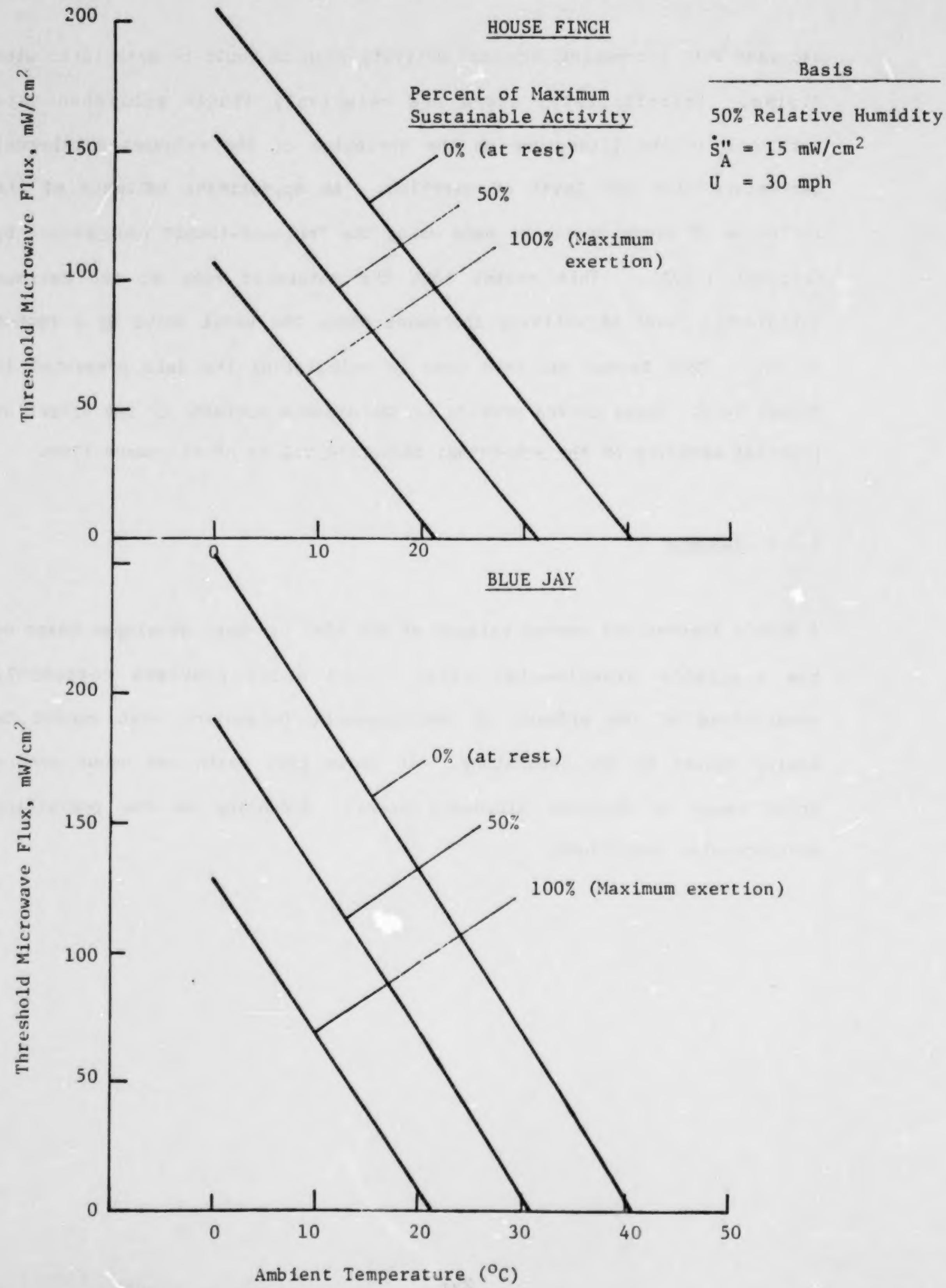


decrease with increasing physical activity such as would be associated with flying. Unfortunately, there are relatively little published data available in the literature on the variation of the relevant biothermal parameters with the level of exertion. An approximate estimate of the influence of exertion can be made using the "rule-of-thumb" recommended by Campbell (1977). This states that the metabolic rate at the maximum sustainable level of activity increases above the basal value by a factor of ten. This factor has been used in calculating the data presented in Figure 5-10. These curves provide an approximate estimate of the effect of physical activity on the sub-lethal threshold values of microwave flux.

5.1.6 Summary

A simple theoretical energy balance of the bird has been developed based on the available experimental data. This model provides reasonable predictions of the effects of environmental parameters that cannot be easily tested in the laboratory. It shows that death can occur over a broad range of incident microwave energy, depending on the prevailing environmental conditions.

Figure 5-10. Predicted Effect of Physical Activity on Maximum Tolerable Flux Levels



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5.2 MICROWAVE DOSIMETRY

The purpose of the microwave dosimetry effort was to determine the specific absorption rate (S.A.R.) of various types of birds as a function of their posture and orientation with respect to the E vector of the 2450 MHz microwave field. Two different types of calorimetric experiments were conducted. The first entailed the placement of a live bird in an insulated, microwave-transparent container, followed by irradiation with microwaves of known power density and polarization, and measurement of the rate of temperature rise of the bird. The second entailed the placement of a dead bird in an oven, preheating it to a fixed temperature, and allowing it to reach thermal equilibrium with a known amount of water in a Dewar to determine its specific heat.

The S.A.R. for a given species and weight was calculated by the

$$\text{S.A.R.} = \frac{\text{mW absorbed}}{(\text{Wt. of bird}) \quad (\text{power density})}$$

$$= \frac{\text{mW}}{(\text{Wt.})\left(\frac{\text{mW}}{\text{cm}^2}\right)}$$

$$= \frac{\text{Cal/minute}) \quad (69.769)}{(\text{Wt.})\left(\frac{\text{mW}}{\text{cm}^2}\right)}$$

$$= \frac{(\ \Delta T^\circ/\text{minute})\ (\text{Sp. Heat})\ (69.769)}{\left(\frac{\text{mW}}{\text{cm}^2}\right)}$$

where (ΔT^{o}/minute) is the slope of the heating curve and (mW/cm^2) is the power density of the irradiating field.

A more detailed description of the procedures utilized is given below.

5.2.1 Irradiation

5.2.1.1 Equipment

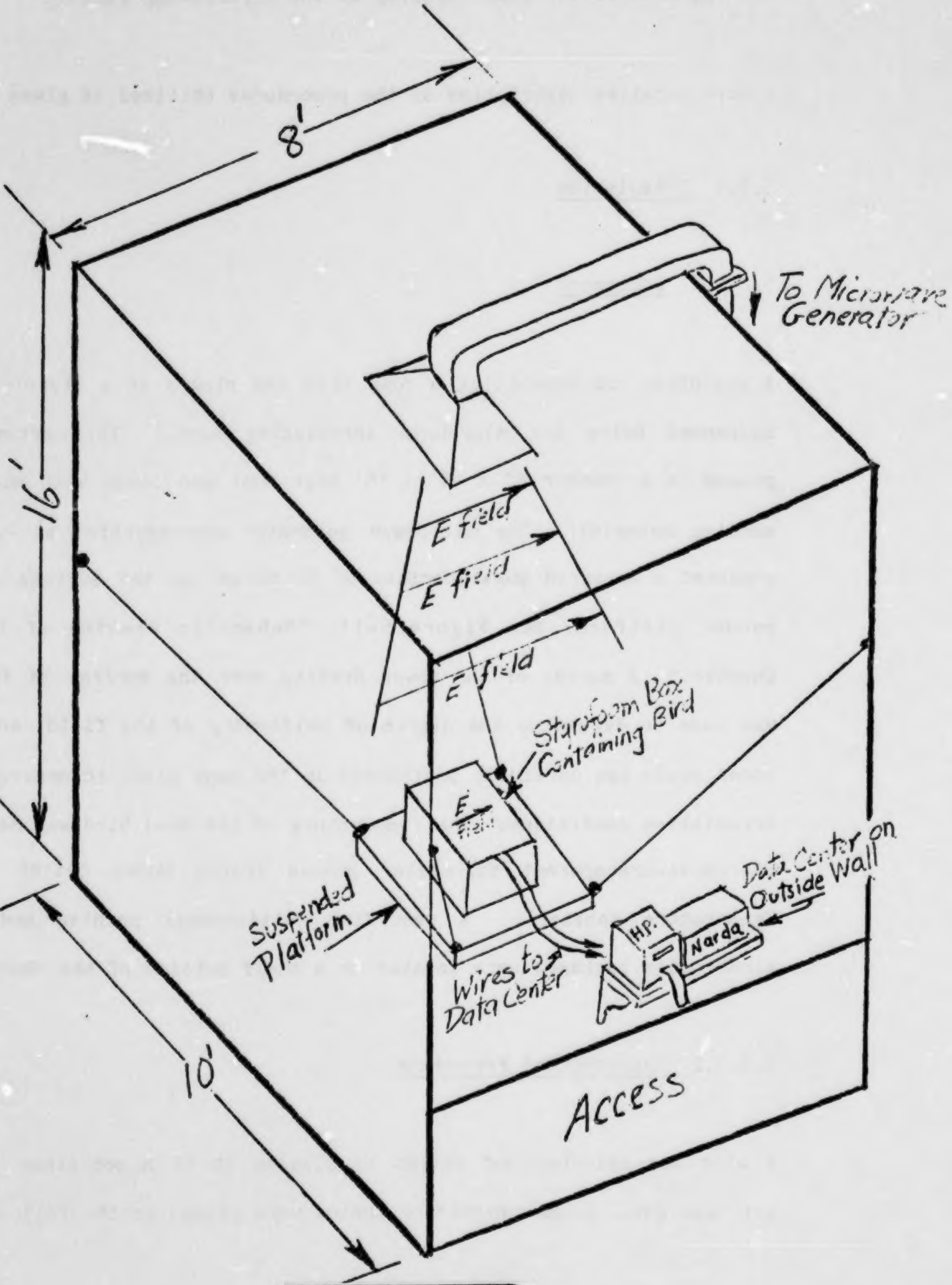
A styrofoam box containing a dead bird was placed on a styrofoam platform suspended below the microwave irradiating horn. This arrangement was placed in a chamber 8' x 10' x 16' high that was lined with microwave absorbing material. The microwave generator was operated at [illegible].6 Kw which produced a measured power density of 92 mW/cm^2 at the surface of the suspended platform; see Figure 5-11, "Schematic Drawing of Irradiation Chamber." A survey of the power density over the surface of the platform was made to determine the degree of uniformity of the field, and each bird under study was carefully positioned in the same place to ensure repetitive irradiation conditions. The temperature of the dead bird was measured with microwave-transparent thermistor probes (Narda Model 8011RF Transparent Temperature Monitor). A recording multichannel printer and the Narda electronics packages were located on a shelf outside of the chamber.

5.2.1.2 Experimental Procedure

A bird was selected and killed by placing it in a container filled with nitrogen gas. Narda thermistor probes were placed in the following manner:

Figure 5-11

Schematic of Irradiation Chamber


8'
16'
10'
To Microwave Generator
E field
E field
E field
E field
Styrofoam Box Containing Bird
Data Center on Outside Wall
HP.
Narda
Suspended Platform
Wires to Data Center
Access

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1. into the approximate center of the body via the cloaca,

2. into the center of the head through the roof of the mouth,

3. on the skin in the axilla (wing) next to the body, and

4. on the ventral surface of the wing over the metacarpal joint.

The instrumented bird was placed on a plastic net suspended 2.5 cm above the floor of a styrofoam box whose inside dimensions were (40 cm long) x (28 cm wide) x (10.5 cm high) and a wall thickness of 5 cm. When necessary the bird was secured in place with string. The thermistor probes were previously passed through a hole in the wall of the chamber and connected to the instrumentation for recording temperatures.

Measurements were made on each bird during irradiations in each of four different positions:

1. Wings folded close to body with body oriented parallel to the E vector.

2. Wings folded close to the body with body oriented perpendicular to the E vector.

3. Wings spread with body oriented parallel to the E vector.

4. Wings spread with body oriented perpendicular to the E vector.

Orientation with respect to the E vector was accomplished by rotating the box containing the bird on the suspended platform while taking care to keep the bird in the same place in the field. Experiments involving wings spread versus wings folded positions required manipulation of the bird within the box and securing the wings in place.

Initially, the "core" temperature of a freshly killed bird was equilibrated to a value near that of room temperature (ca. 20°C). With the box and bird in place, the microwave generator was turned on and adjusted to the proper power level (92 mW/cm^2). The temperature recorder was activated and temperature signals from thermistor probes were recorded (temp vs. time). After the bird had warmed to about 45°C, the microwave power source was turned off, the temperature recorder stopped, and the box was opened.

The bird was then rapidly cooled in order to return the bird to a temperature of approximately 20°C by placing a plastic bag filled with ice over the bird or by pouring liquid nitrogen adjacent, but not on, the bird and closing the box.

After cooling, the orientation of the bird was changed and the process of irradiation repeated until measurements on all four (previously mentioned) positions were obtained and recorded. Each bird was weighed before irradiation and again immediately prior to the calorimetry procedure that followed irradiation.

5.2.2 Calorimetry

5.2.2.1 Equipment

A one (1) liter wide-mouth glass Dewar flask with a polyethylene foam cap or closure served as the calorimeter. An incubator set at 45°C was used to heat the dead bird.

5.2.2.2 Procedure

A known mass of cold water, the amount depending on the size of the bird, was placed in the Dewar with a calibrated thermistor temperature sensor. A second thermistor was placed in the center of the bird's body and the bird heated to 40-45°C in the incubator. Upon reaching this temperature, the bird (with its thermistor) was submerged into the water in the Dewar and capped with the foam stopper. The temperatures of the cool water and of the heated bird were recorded simultaneously until both temperatures were the same.

Although most birds used for calorimetry had their feathers removed, measurements were also made on several birds with feathers.

5.2.2.3 Calculation

A calorimeter constant was determined by pouring hot water of a known mass and temperature into the cool Dewar of known temperature, measuring the new equilibrium temperature, and then calculating the calories per degree of temperature change in the glass walls of the Dewar.

The average of four determinations yielded 39.2 Cal/C^{o}.

The specific heat of the bird was calculated by:

$$S = \frac{(39.2 + m_2)(t_3 - t_2)}{m_1(t_1 - t_3}$$

where: m_1 = mass of bird

m_2 = mass of water

t_3 = final temperature

t_2 = water temperature at start

t_1 = bird temperature at start

s = specific heat (gram-calories gram^{-1} C^{o-1})

5.2.3 Data Processing

The printed records of temperature (recorded as a voltage) and time were placed on magnetic tape and computer processed. Voltages were converted into temperatures according to equations generated from calibrations of the Narda probes against a standard temperature reference, and a file was created from which curves of temperature rise versus time were plotted.

The slopes of the plotted curves were measured in degrees of angle ø on the drafting table and converted into slope (ΔT/min) using the form: $m = k \tan ø; k - 1.3323$.

5.2.4 Data Analysis -- Method

The apparatus was tested using a thin plastic bag containing 90.8 grams of water to simulate a bird. The heating curve for the water is presented in Figure 5-12. The linearity of the heating curve allows a simple determination of the slope of the curve (0.5701°/min) and the SAR:

$$\text{SAR} = \frac{(0.5701)\ (1)\ (69.769)}{(92)}$$

$$\text{SAR} = 0.4323\ \text{mW/g/mW/cm}^2$$

Figure 5-13 is a plot of the temperature rise of a typical bird (House Finch #1) when exposed with the body parallel to the E field, and when wings were folded (House Finch 1/wf). This curve shows that the slopes of the body and head curves are nearly linear between 20° and 43°C.

The measured slopes at different parts of the heating curves are marked on the curves shown in Figure 5-13. The slope over a large part of the heating range of the body curve is seen to be 2.22.

Figure 5-14 is the heating curve for the same bird as in Figure 5-13, with wings folded, but the body was perpendicular to the E-field. Note that the slopes are less than in Figure 5-13. Slopes were measured at various

Figure 5-12. Heating Curve of 90.8 g of Water Contained Within a Plastic Bag

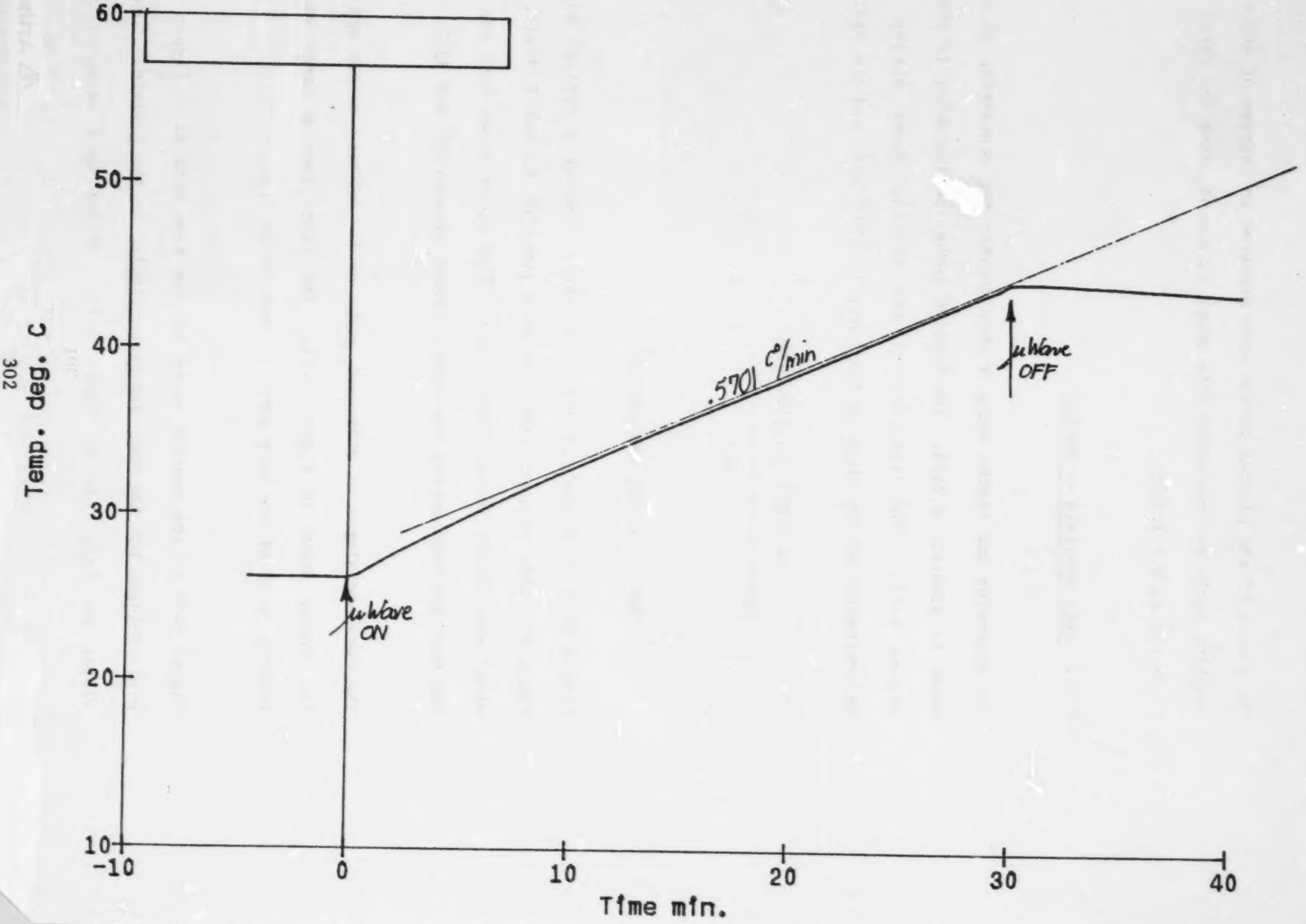


Figure 5-13. Heating Curve of House Finch (Parallel Orientation, Wings Folded)

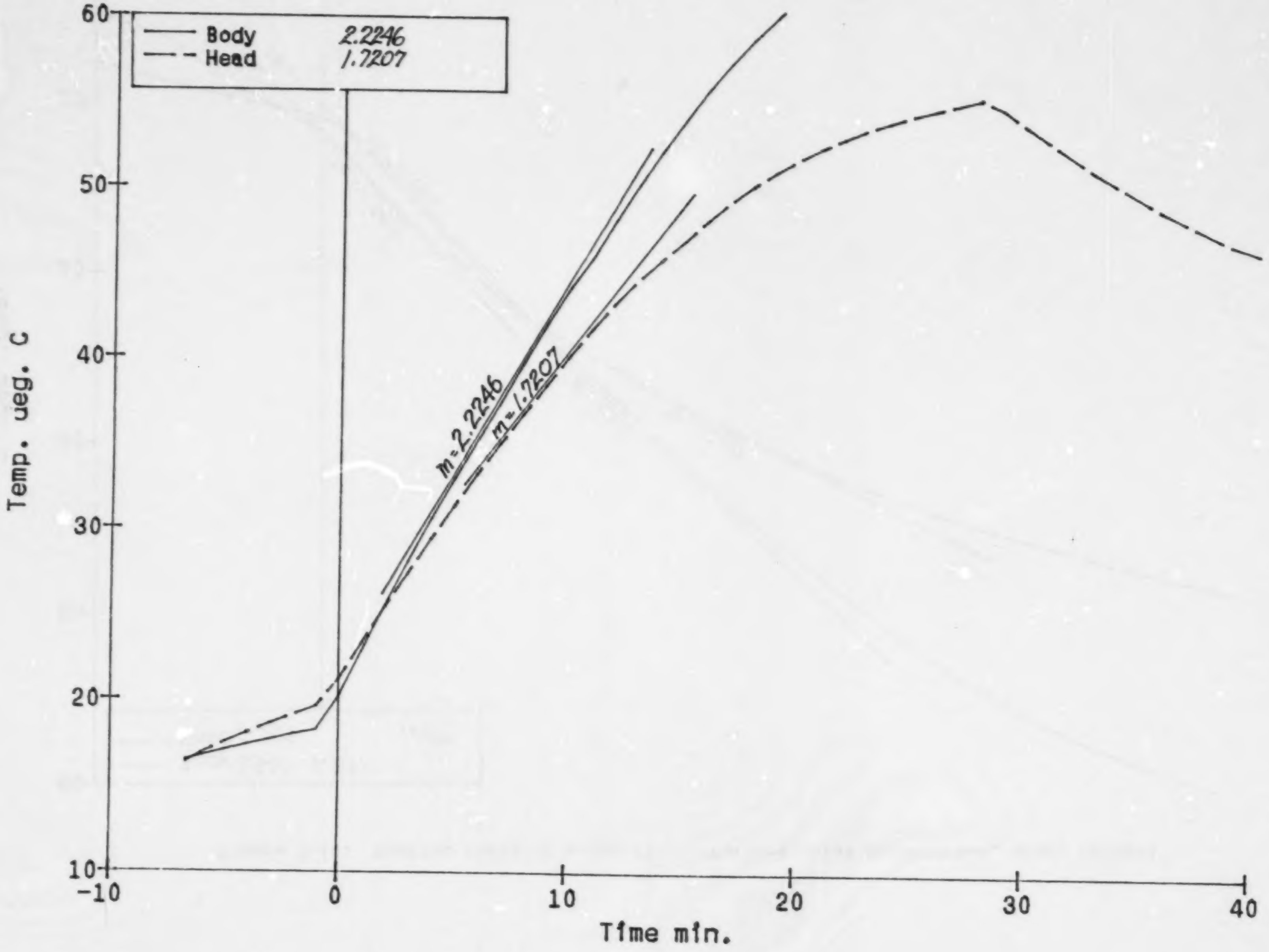
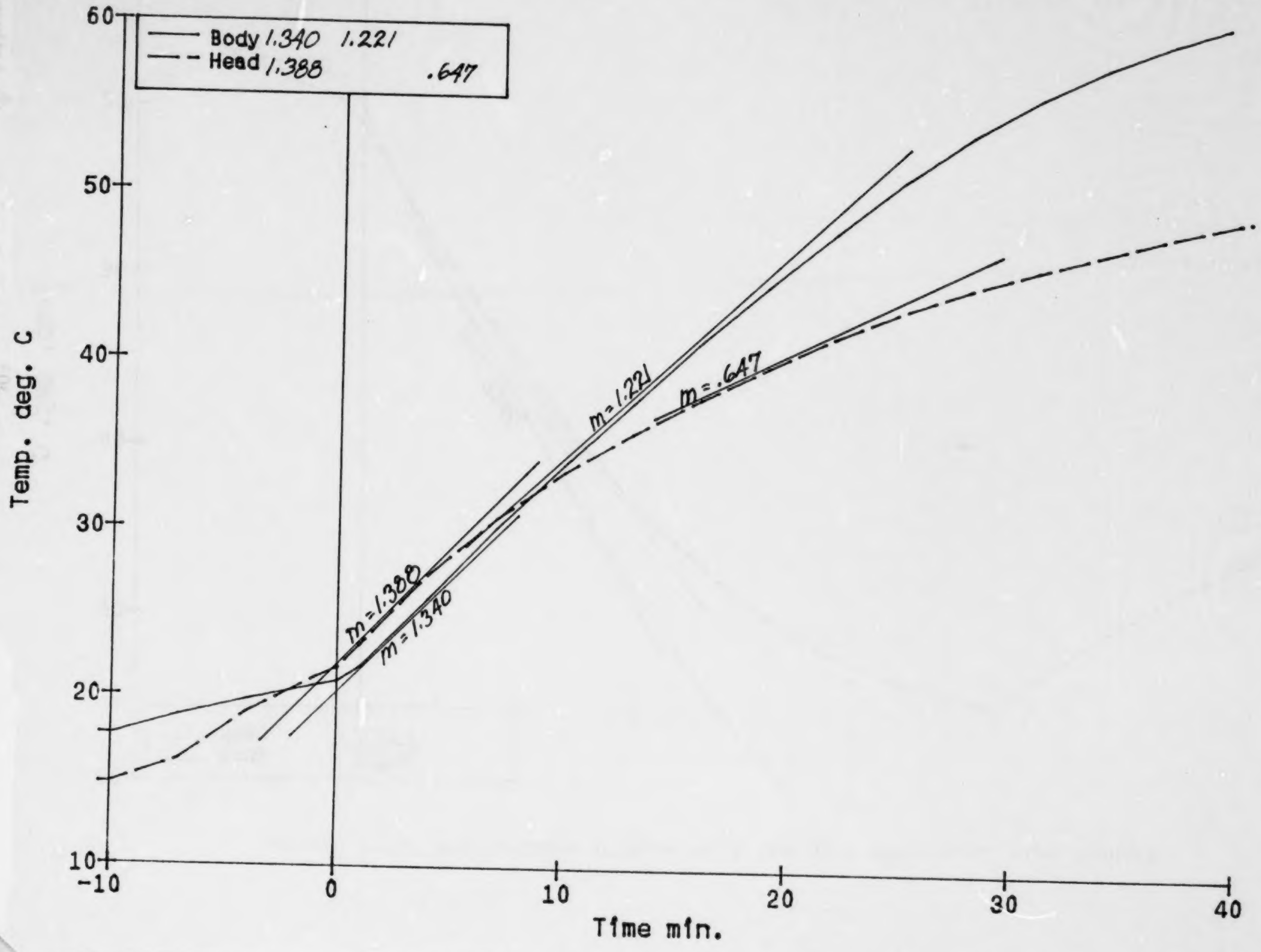


Figure 5-14. Heating Curve of House Finch (Perpendicular Orientation, Wings Folded)



places along the curves because of the curvature, and the values are given in the title box. The left most value for the slope was obtained at the beginning of the heating and the value at the right is the slope at the end of the heating period.

The central, most linear part of the body temperature versus time curve has a slope of 1.22. It was these slopes that were used in subsequent calculations of S.A.R.

5.2.5 Results and Discussion

A summary of specific heats obtained by this method for a number of bird species is presented in Table 5-1. Calorimetry was carried out on birds with and without feathers and some birds were irradiated before calorimetry whereas in other calorimetry measurements were made on freshly killed birds. Since a bird may lose up to 10 percent of its mass by moisture loss during irradiation, the specific heat of freshly killed birds more nearly represents the specific heat of a live bird.

Examination of the specific heats presented in Table 5-1 reveals considerable variability. There are many values greater than 1.0 (an unlikely value) as well as variability in specific heats for a given species. Data suggest that smaller birds produced highly variable results (e.g., 8-14 gram Zebra Finch).

The average specific heats of birds with feathers removed (by plucking) by bird type in order of increasing mass are presented in Table 5-2. Values

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Table 5-1 SUMMARY OF MEASURED SPECIFIC HEATS OF BIRDS

BIRD IDENT.		WEIGHT PLUCKED	SP. HEAT PLUCKED	WEIGHT FEATHERED	SP. HEAT FEATHERED	DATE	
Coturnix Quail	1	148.07	.84			7/29	Irradiated first
	2	182.24	.94	182.24	.97	8/6	Calorimetry only
Average		165.16					
Blue Jay	FK3	81.94	.73			7/10	Irradiated first
	FK4	82.24	.75	89.97	.79	7/12	Calorimetry only
	X	64.44	.90	69.44	.94	7/10	Irradiated first
	FK5	74.05	.98	80.59	1.01	8/3	Calorimetry only
	FK6	61.17	1.06			8/6	Irradiated first
Average		72.7					
White Throated Sparrow	1	28.	.83; .85			6/30	Irradiated first
	2	25.21	.84			7/1	Irradiated first
	3	18.20	.99			7/25	Irradiated first
	4	34.7	.92	36.5	1.09	7/31	Calorimetry only
	5	27.42	1.13	28.59	1.33	8/1	Calorimetry only
	6	25.37	.69	27.1	1.28	8/3	Calorimetry only
Average		26.48					
Budgerigar	1	29.4	.88			6/24	Irradiated first
	2	25.4	.99			7/17	Irradiated 6 times*
	4	28.34	1.26			8/4	Irradiated first
Average		27.71					
House Finch	1	13.96	.98			7/20	Irradiated first
	2	14.79	.87			7/23	Irradiated first
	4	18.75	1.02	12.04	1.34	7/31	Calorimetry only
Average		15.83					
Zebra Finch	2	8.31	1.17			7/21	Irradiated first
	3	10.71	1.60			7/24	Irradiated first
	4	11.36	1.07	19.2	1.02	7/30	Calorimetry only
	5	14.34	.89	14.98	1.16	7/30	Calorimetry only
Average		11.18					

* Reproducibility Experiment

of specific heat greater than 1 have been included in the averages.

The literature data summarized in Table 5-3 show a range of 0.72 to 0.80 for the specific heat of unfrozen poultry. These data are derived from the moisture content using Siebel's formula*:

$$S = 0.008a + 0.20$$

where a = % water content; S = Sp. heat;

0.2 is considered to be the sp. ht. of the solid constituents

Presumably, the poultry listed in Table 5-3 were drained of blood whereas birds used in this study were not. This would yield a higher moisture content for our birds and hence a somewhat higher specific heat.

Among other products listed in Table 5-3 are oysters with a moisture content of 87% and a Sp. Ht. = 0.896, and milk with 87.5% moisture and Sp. Ht. = 0.900. These specific heats indicate a probable upper limit above which our birds are not likely to go.

---

*Parkery, Harvey, Stateler, Elements of Food Engineering, Vol. II, Reinhold 1954.

Table 5-2

Mean Specific Heats of Birds With Feathers Removed

Bird Type	Number of Birds	Average Weight	Average Specific Heat Plucked (σ)		Comments
Zebra Finch	4	11.18g	1.18	(.26)	3 of the 4 greater than
House Finch	3	15.83	.96	(.06)	1 of the 3 greater than
White Throated Sparrow	6	26.48	.89	(.13)	1 value greater than 1 1 bird measured twice
Budgerigar	3	27.71	1.04	(.16)	1 value greater than 1
Blue Jay	5	72.76	.88	(.13)	1 value greater than 1
Coturnix Quail	2	165.16	.89	(.05)	
Average of all measurements			.97	(.19)	

There seems to be no correlation between bird weight or type and specific heat.

Referring to a Table of Specific and Latent Heats of Various Food Products,* we find the following compilation (in part):

Table 5-3

Specific Heats of Various Animal Products

	% Water	Specific Heat[+] Above Freezing
Poultry Dressed Iced	73.7	.790
Poultry Dry Picked	65.0	.720
Poultry Scalded	75.0	.800
Oysters (no shell)	87.0	.896
Milk	87.5	.900

---

* Lange, N.A., Handbook of Chemistry, Fourth Edition (1941) p1206.

[+] $\frac{mW/g}{mW/cm^2}$

Because of the relative masses of the birds and the calorimeters, one might expect more error in measurements of the smaller birds. This tends to be borne out by our results. The average specific heat for our two largest birds -- Coturnix Quail and Blue Jay - is .886 ±.112 which is the value to be used in computating the S.A.R.

Orientation of Bird in Microwave Field

The bird generally has an elongate shape. It is expected that the bird orientation will affect the specific absorption rate, and for small birds, this absorption will be maximized when the body is aligned with the E-field. Additional tuning-effects may be present for larger birds when dimensions yield an electrical length comparable to or greater than 1/2 the wavelength of the incident radiation. Since the E-field interaction and absorption of microwave energy may also be affected by the spreading of the bird's wings, we irradiated each bird four times, i.e., parallel and perpendicular to the field and with wings folded and wings spread in each orientation.

Feathers

The effect of feathers on specific absorption rate was not determined directly but is believed to be small. Birds were irradiated with feathers but, because of the low moisture content, poor longitudinal thermal and electrical conductivity, low percentage of total bird mass, and small dimensions of each feather, it is likely that the small amount of heat generated in the feathers did not propagate thermally to the body of the bird, nor would the feathers be expected to influence the coupling between the body of the bird and the microwave field. The principal effect of the feathers is to thermally insulate the body of the bird and any feather heating would merely serve to make the body heating more nearly adiabatic. The feathers were left on the birds for irradiation to minimize the elapsed time (to pluck the bird) between killing the bird and irradiating it, but they were then removed, except where indicated, before the calorimetry measurement for specific heat as made.

Power Level and Heat Loss

The power level used in the dosimetry experiments was increased from 25 mW/cm^2, the maximum power level used for most of the long-term experiments, to 92 mW/cm^2 in order to produce more rapid heating of the bird. More rapid heating reduced the need for a heat loss correction and shortened the duration of each experiment to an acceptable period. The styrofoam box used to contain the birds was found to be slightly heated by the microwave radiation which further reduced the need for a heat loss correction. The curvature in the temperature rise versus time curves reduces the precision with which a slope can be determined and hence the precision of an S.A.R. value derived from the slope. A heat loss correction would not materially affect the results of the S.A.R. calculations.

There was no correction applied for heat loss from the styrofoam box during the irradiation of the birds.

Without Feathers (Plucked) versus Feathered

As mentioned above, feathers were not removed before a bird was irradiated. Since it is believed that most of the absorption of microwave energy is in the moist flesh of the bird and since the specific heat of the part of the bird that absorbs the radiation must be determined, the birds were plucked and weighed for the specific heat measurement. When computation of the S.A.R. is made, the mass of the bird, used in both numerator and denominator, cancels out so that the

S.A.R. = 69.769 x (slope of temperature vs. time curve) x (specific heat)

and is independent of the weight of the bird.

Calorimetry was conducted on birds with feathers as well as without feathers but the variability in the data precludes drawing precise conclusions about the effect of feathers on specific heat.

Specific Heat

Calorimetry was conducted on several birds to determine their specific heats. The variability in the results was large and believed due to factors related to the ratio of masses of birds to that of the calorimetric apparatus, i.e., small birds weighed so little compared to the weight of water and the calorimeter constant that accuracy was poor. It is for this reason that an average specific heat was calculated from specific heats measured for our two largest birds only, and this specific heat value (0.886 ±.112) was used in all the S.A.R. calculations.

Heating Curves

When a weighed amount of water is heated on our apparatus (See Figure 5-12), the rate of heating is linear. When a bird is heated in the same apparatus, the observed rate of heating is (usually) rapid at first, then settles to a nearly linear rate, and then falls off further, as higher temperatures are reached. It is not possible to explain in detail the processes that take place within the bird due to the complexity of the animal body. A bird has body cavities, bone, fat and flesh distributed unevenly throughout the mass, each of which has a different dielectric constant, electrical and thermal conductivity. Certain regions of the bird will heat more rapidly than others and in these experiments heat will flow to cooler areas at rates depending on thermal conductivities. There is also some uncertainty as to the exact anatomical position of the temperature probe within the bird, and it is difficult to place the probe in the same site in different size and species of birds. In the case of the water contained in a plastic bag there was free convection within the bag and the observed heating process was, as expected, a linear function of time.

Reproducibility Experiment

The reproducibility of the irradiation process was tested with dead Budgerigar #2, which was irradiated six times. Probes were inserted in the bird and the bird fastened in the styrofoam box. After each irradiation, the hot bird was cooled by draping an ice pack over the bird. The first three experiments were conducted without disturbing the bird, box, or platform except to remove the lid of the box to cool the bird.

In experiment 4 the box was intentionally moved 1-1/4 inches to the left of center on the irradiating platform. In experiment 5 the box was moved 1-1/4 inches to the right of center on the platform and in experiment 6 the box was taken off the platform and replaced centrally in the normal position on the platform. Figure 5-15 is a composite plot of body temperature of all six experiments. The bird was oriented with its body parallel to the E vector with its wings folded. The bird weighed 30.71 grams at the start of the experiment and weighed 27.96 grams at the end, a loss of mass of 2.75 grams (9%) after six exposures totaling 2.78 hours.

Table 5-4 is a summary of the measured slopes of the heating curves for all six experiments. The slope of each curve was measured at the beginning, middle (linear), and at the high (43-45°) temperature range. If one were to choose one region of the heating curve as being most predictive, it would be the mid-points where a quasi-equilibrium heating rate is established, and where non-linearities of the temperature measuring equipment, heat losses, and progressive dehydration of the birds have less significance than they do at the higher temperatures.

Many of the birds were plucked for calorimetry and photographed against a centimeter grid. Measurements of the length and width of the heads and bodies, exclusive of neck, are presented in Table 5-5.

Summary of S.A.R.'s for All Birds

Table 5-6 is a summary of the S.A.R.'s for 15 birds arranged in order of increasing mass and grouped according to the configuration and orientation

Figure 5-15. Heating Curves of Budgerigars Produced in Reproducibility Experiment

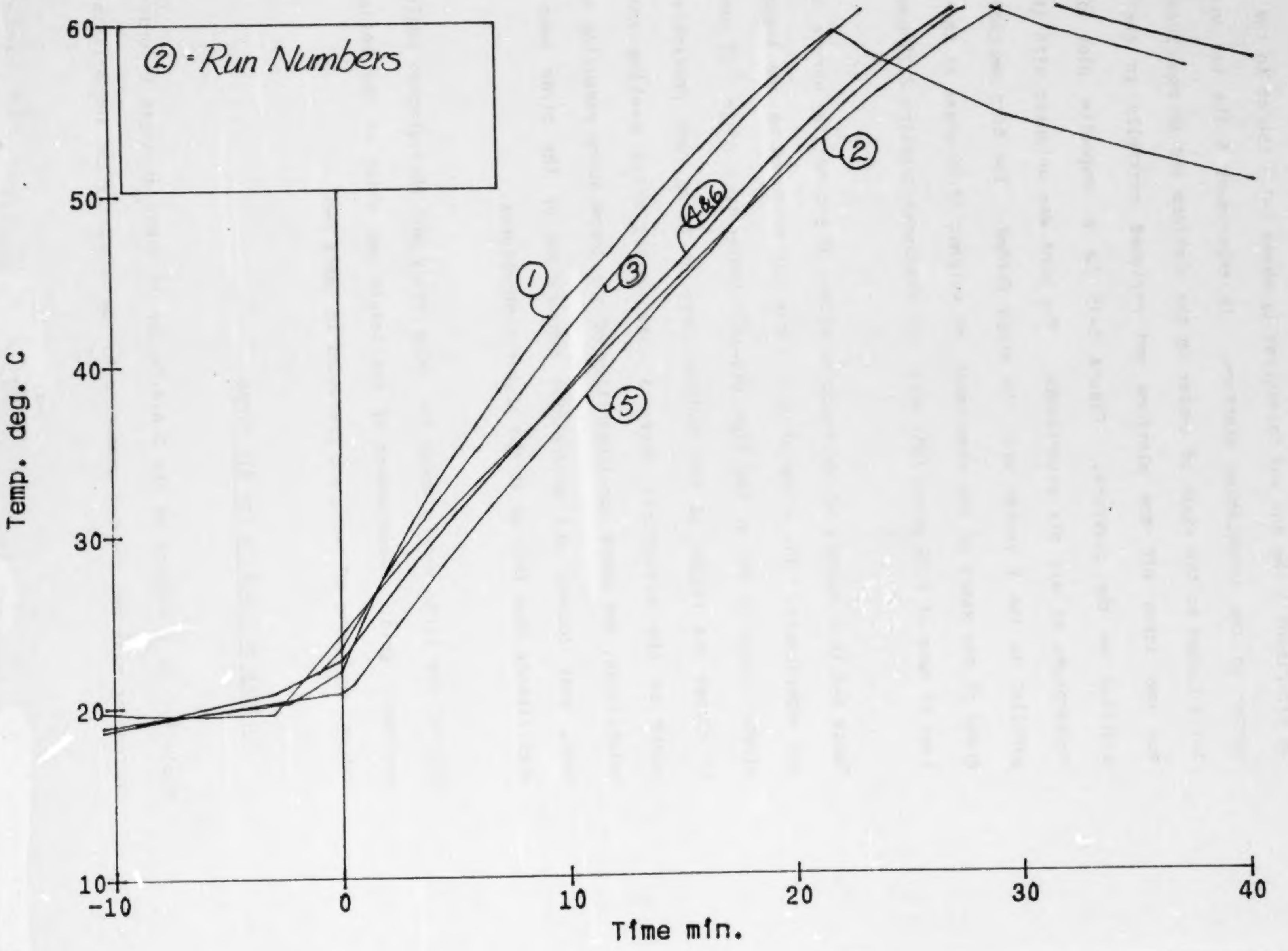

TABLE 5-4

SLOPE OF HEATING CURVES (°C/MIN)

Budgerigar 2 - Parallel to E vector - Wings Folded

Run No.		Head			Body		
		Start	Mid	End	Start	Mid	End
1		3.040	2.454	2.181	2.804	1.891	1.551
2		4.358	3.139	2.762	1.953	1.317	1.317
3		3.471	2.506	2.506	1.675	1.675	1.616
4		2.269	2.269	1.807	1.680	1.467	1.467
5		2.762	2.105	2.105	1.645	1.519	1.519
6		2.355	1.817	1.429	1.569	1.429	1.429
Averages		3.04	2.38	2.13	1.89	1.55	1.48
	σ	.715	.409	.436	.427	.186	.095
SAR*		2.70	2.11	1.89	1.67	1.37	1.31
	σ	.72	.42	.45	.44	.22	.15

*Calculation of SAR assumes a specific heat of .886 σ = .112 for both the head and the body of the bird.

TABLE 5-5

AVERAGE MEASURED DIMENSIONS OF BIRDS

Species	Number of Birds Measured	Body - Cm		Head - Cm	
		Length (σ)	Width (σ)	Length (σ)	Width (σ)
Zebra Finch	2	3.8 (.6)	1.7 (0)	1.6 (0)	1.3 (0)
White Throat Sparrow	4	4.9 (.7)	2.6 (.3)	2.1 (.2)	1.8 (.1)
House Finch	1	4.4	1.8	1.9	1.5
Budgerigar	3	5.6 (.2)	2.5 (.1)	2.1 (.1)	1.7 (.1)
Blue Jay	3	6.9 (.3)	3.3 (.2)	3.2 (.2)	2.7 (.1)
Coturnix Quail	1	11.3	4.3	2.4	2.1

Table 5-6. Summary of S.A.R. for All Birds

$$SAR = (.7584)\ (\text{Sp. Ht.})\ ({}^{\Delta T}/_{\Delta t})$$

$$\text{Sp. Heat} = .886 \quad \sigma = .112$$

Species	No. of Birds	Average Weight Grams	$^{\Delta T}/_{\Delta t}$ C°/min	S.A.R. (σ)	$^{\Delta T}/_{\Delta t}$ C°/min	S.A.R. (σ) $\frac{mW/g}{mW/cm^2}$
	Body Parallel to E field - Wings Folded					
Zebra Finch	3	11.18	2.74 (.09)	1.84 (.14)	1.71 (.39)	1.15 (.41)
House Finch	2	15.83	2.69 (.47)	1.81 (.48)	1.63 (.09)	1.09 (.14)
White Throated Sparrow	3	26.48	1.80 (.25)	1.21 (.27)	2.38 (.35)	1.60 (.37)
Budgerigar	3*	27.71	1.60 (.23)*	1.08 (.26)*	2.24 (.48)*	1.47 (.49)*
Blue Jay	2	72.76	1.15 (.05)	.77 (.12)	1.79 (.46)	1.20 (.47)
Coturnix Quail	2	165.16	.54 (.05)	.36 (.12)	.64 (0)	.64 (.11)
	Body Perpendicular to E field - Wings Folded					
Zebra Finch	3	11.18	.86 (.10)	.58 (.15)	.46 (.09)	.31 (.14)
House Finch	2	15.83	1.23 (.01)	.83 (.11)	.89 (.12)	.60 (.16)
White Throated Sparrow	3	26.48	1.26 (.46)	.85 (.47)	.96 (.27)	.64 (.29)
Budgerigar	2	27.71	.95 (.02)	.64 (.11)	1.05 (.11)	.71 (.16)
Blue Jay	3	72.76	.76 (.03)	.51 (.12)	1.23 (.27)	.83 (.29)
Coturnix Quail	2	165.16	.46 (.02)	.31 (.11)	.58 (.04)	.39 (.12)

Table 5-6. Summary of S.A.R. for All Birds (continued)

Species	No. of Birds	Average Weight Grams	$\Delta T/\Delta t$ C°/min	S.A.R. (σ)	$\Delta T/\Delta t$ C°/min	S.A.R. (σ) $\frac{mW/g}{mW/cm^2}$
	Body Parallel to E Field - Wings Spread					
Zebra Finch	3	11.18	2.78 (.57)	1.87 (.58)	1.62 (.55)	1.09 (.56)
House Finch	2	15.83	2.68 (.10)	1.80 (.15)	1.86 (.22)	1.25 (.25)
White Throated Sparrow	3	26.48	1.78 (.04)	1.20 (.12)	2.14 (.39)	1.44 (.41)
Budgerigar	2	27.71	2.62 (1.04)	1.76 (1.05)	2.98 (.57)	2.00 (.58)
Blue Jay	3	72.76	1.03 (.08)	.69 (.14)	1.94 (.49)	1.30 (.50)
Coturnix Quail	2	165.16	.50 (.06)	.34 (.13)	1.08 (.04)	.73 (.12)
	Body Perpendicular to E field - Wings Spread					
Zebra Finch	3	11.18	1.81 (.06)	1.22 (.12)	.58 (.14)	.39 (.18)
House Finch	2	15.83	1.31 (.17)	.88 (.20)	.76 (.04)	.51 (.12)
White Throated Sparrow	3	26.48	1.26 (.07)	.85 (.13)	1.63 (.08)	1.09 (.14)
Budgerigar	2	27.71	1.21 (.03)	.81 (.12)	2.27 (.94)	1.52 (.95)
Blue Jay	3	72.76	.79 (.09)	.51 (.14)	1.18 (.18)	.79 (.21)
Coturnix Quail	2	165.16	.52 (.06)	.35 (.13)	1.22 (0)	.82 (.11)

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* One budgerigar was irradiated six times in this position for a reproducibility experiment. The bird slopes were arranged with those of the other two birds to produce a total sample of eight slopes.

of the bird during irradiation. The average mid-slope of the heating curves is given as well. Computation of S.A.R. is based upon a common specific heat value of .886; = .112 and the average mid-slope of the heating curves. The specific heat of bird heads was not determined separately and so the S.A.R. for the heat portion may not be meaningful in-as-much as the head probably has a higher ratio of bone to flesh than the body.

In general, there is a higher S.A.R. when the body is parallel to the E vector, the significance being less for larger birds. The effect of wing spreading is greater with smaller birds when the body is perpendicular to the E field.

Temperature Correction

The original plotted curves in the Appendix are in error at their extrema. Subsequent calibration of the Narda temperature probes enabled corrections to be made manually during the measurement of slopes on the drafting table. The computed slopes are therefore correct even though the displayed curves are somewhat in error.

The illustrative examples of heating curves in the body of the report have been corrected by the computer and these curves therefore will differ slightly from their counterparts in the Appendix.

The magnitude of the correction for a House Finch is illustrated in Figures 5-16 and 5-17.

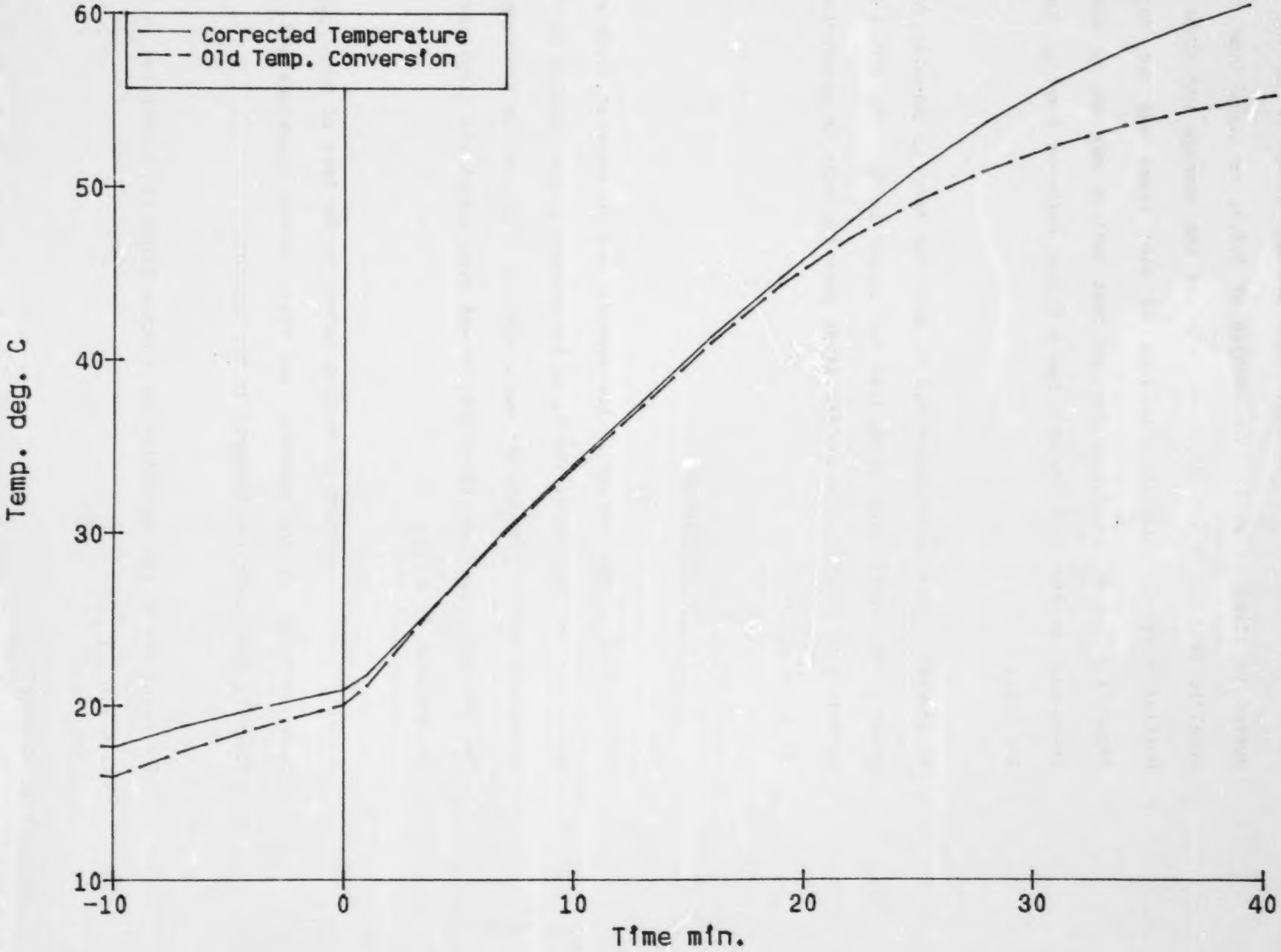
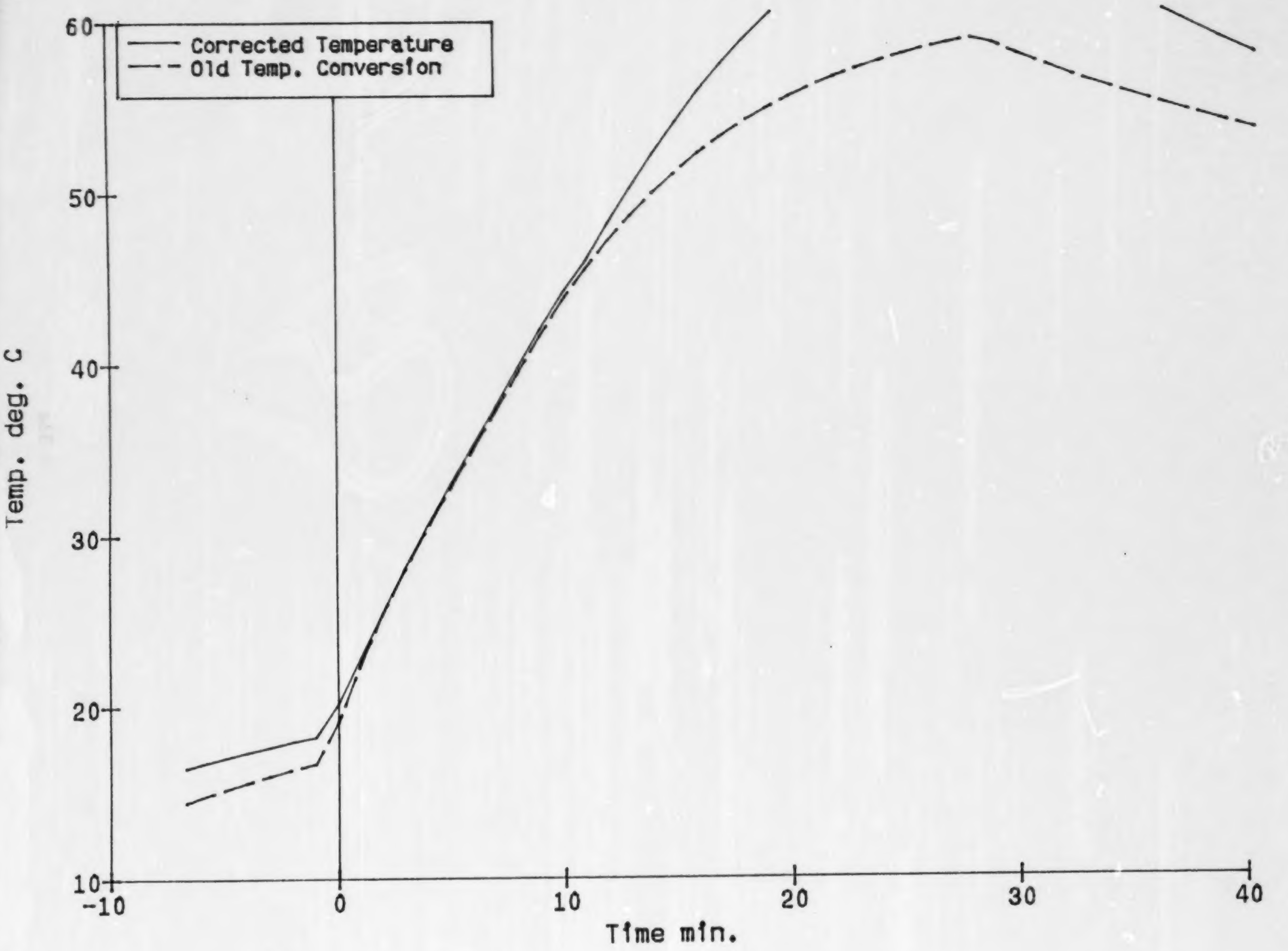


Figure 5-16. Original and Corrected Heating Curve for House Finch (Perpendicular Orientation, Wings Folded)

Figure 5-17. Original and Corrected Heating Curve for House Finch (Parallel Orientation, Wings Folded)



APPENDIX A -- SECTION 4

TABLE A4.1-4

SUMMARY OF INDIVIDUAL DATA ON THE AVERSION/ATTRACTION EXPERIMENTS ON BLUE JAYS IRRADIATED AT 10 mW/cm^2

BIRD	TRIAL	T^oC	P	S	F	E	SH	P	S	F	E	SH	P	S	F	E	SH	RH
LB-W	1	20.5	100	0	0	68	32	100	0	0	0	100	100	0	0	23	77	48
LB-W	2	20.5	100	0	0	100	0	99	0	1	94	5	100	0	0	82	18	48
G-R	1	20.5	100	0	0	0	100	82	2	16	30	54	62	4	24	33	43	48
G-R	2	20.5	74	1	25	36	39	74	1	25	32	43	84	0	16	36	48	48
DB-	1	18.9	98	0	2	48	50	93	0	7	65	28	97	0	13	32	55	45
DB-	2	19.4	100	0	0	100	0	100	0	0	95	5	50	0	50	24	26	44
LB-	1	19.4	100	0	0	0	100	100	0	0	59	41	99	1	0	78	22	43
LB-	2	18.9	100	0	0	92	8	94	6	0	44	56	100	0	0	0	100	43.5
-G	1	18.9	100	0	0	100	0	100	0	0	0	100	100	0	0	0	100	79
-G	2	18.9	100	0	0	0	100	96	0	4	22	74	74	0	26	74	0	81
W-DB	1	18.9	50	0	50	23	27	93	0	7	20	73	100	0	0	0	100	32
W-DB	2	18.9	55	3	42	37	21	51	2	47	29	24	80	0	20	72	8	33
-R	1	18.3	100	0	0	10	90	100	0	0	0	100	100	0	0	6	94	43
-R	2	18.9	100	0	0	100	0	66	0	34	39	27	44	0	56	25	19	41
-LB	1	17.8	81	0	19	29	52	90	0	10	63	27	55	1	44	10	46	31
-LB	2	18.3	40	1	59	19	22	26	0	74	13	13	71	0	19	38	33	31
-W	1	18.9	98	0	2	48	50	93	0	7	58	35	97	0	3	64	33	31
-W	2	18.9	100	0	0	16	84	99	0	1	38	61	92	0	8	52	40	31
-DB	1	18.9	100	0	0	100	0	100	0	0	100	0	95	0	5	4	91	35
-DB	2	18.9	100	0	0	0	100	100	0	0	4	96	68	2	30	26	44	38

TABLE A4.1-5

SUMMARY OF INDIVIDUAL DATA ON THE AVERSION/ATTRACTION EXPERIMENTS ON BLUE JAYS IRRADIATED AT 25 mW/cm^2

BIRD	TRIAL	T°C	P	S	F	E	SH	P	S	F	E	SH	P	S	F	E	SH	RH
LB-W	1	18.9	97	0	3	79	18	100	0	0	58	42	100	0	0	41	59	45
LB-W	2	19.4	100	0	0	40	60	100	0	0	50	50	100	0	0	60	40	43
G-R	1	20.0	100	0	0	96	4	99	0	1	33	66	0	0	100	—	--	39
G-R	2	20.0	96	1	3	15	82	100	0	0	0	100	96	0	4	5	91	39
DB-	1	20.0	18	0	82	5	13	85	0	15	37	48	90	0	10	77	13	83
DB-	2	20.0	82	0	18	35	47	82	0	18	44	38	91	0	9	37	54	91
LB-	1	18.9	100	0	0	0	100	100	0	0	2	98	98	2	0	83	17	38
LB-	2	18.9	100	0	0	60	40	99	1	0	47	53	95	5	0	22	78	36
-G	1	18.3	100	0	0	0	100	100	0	0	0	100	100	0	0	0	100	31
-G	2	19.4	100	0	0	100	0	100	0	0	0	100	97	0	3	93	4	32
W-DB	1	19.4	19	0	81	8	11	30	1	69	18	13	33	2	65	25	8	33
W-DB	2	19.4	46	2	52	17	31	73	1	26	63	11	0	0	100	--	--	33
-R	1	20.6	29	0	71	17	12	13	0	87	8	5	33	0	67	15	18	47
-R	2	20.6	95	0	5	71	24	100	0	0	35	65	71	2	27	57	14	47
-LB	1	20.0	74	0	26	40	34	56	0	44	6	50	18	0	82	12	6	58
-LB	2	20.0	44	0	56	31	13	91	0	9	60	31	45	0	56	28	17	58
-W	1	18.9	100	0	0	93	7	100	0	0	57	43	100	0	0	30	70	62
-W	2	18.9	100	0	0	80	20	100	0	0	43	57	100	0	0	23	77	62
-DB	1	19.4	100	0	0	0	100	100	0	0	0	100	100	0	0	100	0	66
-DB	2	19.4	100	0	0	100	0	100	0	0	100	0	100	0	0	0	100	66

TABLE A4.1-6

SUMMARY OF INDIVIDUAL DATA ON THE AVERSION/ATTRACTION EXPERIMENTS ON BLUE JAYS IRRADIATED AT 50 mW/cm^2

BIRD	TRIAL	T°C	P	S	F	E	SH	P	S	F	E	SH	P	S	F	E	SH	RH
LB-W	1	20.0	100	0	0	35	65	100	0	0	51	49	100	0	0	22	78	58
LB-W	2	20.0	100	0	0	0	100	100	0	0	73	27	98	0	2	46	52	58
G-R	1	20.0	100	0	0	100	0	100	0	0	0	100	100	0	0	100	0	70
G-R	2	20.6	100	0	0	100	0	100	0	0	0	100	100	0	0	0	100	70
DB-	1	19.4	100	0	0	0	100	100	0	0	0	100	97	0	3	39	58	65
DB-	2	19.4	95	0	5	50	45	100	0	0	57	43	99	0	1	57	42	61
LB-	1	18.9	100	0	0	100	0	100	0	0	100	0	100	0	0	0	100	59
LB-	2	19.4	100	0	0	65	35	100	0	0	70	30	100	0	0	57	43	59
-G	1	19.6	100	0	0	0	100	100	0	0	0	100	100	0	0	0	100	60
-G	2	19.6	100	0	0	0	100	100	0	0	0	100	100	0	0	0	100	60
W-DB	1	19.4	15	0	85	5	10	25	0	75	16	9	20	0	71	11	18	54
W-DB	2	19.4	0	0	100	--	--	50	0	50	0	50	0	0	100	--	--	54
-R	1	19.4	100	0	0	76	24	100	0	0	0	100	100	0	0	100	0	49
-R	2	20.0	59	0	41	36	23	48	0	52	24	24	52	0	48	32	20	49
-LB	1	19.4	83	0	17	35	48	100	0	0	24	76	98	0	2	20	78	42
-LB	2	19.4	85	1	14	47	39	100	0	0	75	25	100	0	0	87	13	42
-W	1	18.9	100	0	0	1	99	100	0	0	0	100	99	0	1	2	97	36
-W	2	19.4	100	0	0	100	0	53	0	47	53	0	99	0	1	92	7	36
-DB	1	19.4	100	0	0	100	0	100	0	0	100	0	100	0	0	97	3	39
-DB	2	20.0	100	0	0	97	3	100	0	0	20	80	100	0	0	0	100	39

A4.3-1 Social Interaction Studies -- Facilities and Microwave Equipment

A sheltered site at the foot of an open field was selected for the facility. An area large enough to incorporate the planned building, the newly-added cages and the migratory-oriented-cage platform was cleared of trees and brush. A 2.7 x 3.7 meter steel storage building was erected (Figure A-1). Because the area was now to be used through the winter for the social dominance studies as well as for the spring/fall migration efforts, a double-layer plywood floor and styrofoam wall and ceiling insulation was installed. Windows to allow observation of the surrounding cages and the migratory platform site were cut into the side walls.

A power drop sufficient to supply microwave generators, monitoring instruments and other needs was installed. The 6KW generator to be used for the migratory experiments requires three phase power. However, the nearest source of three phase power is over a mile away where it serves the needs of cranberry bog pumping systems. Because bringing this power source to the study site would be prohibitively expensive, we have elected to use a single-phase to three-phase solid state inverter for the supply to the 6KW source. Table 1 shows the power circuits available at the MBO microwave study site.

Table 1. Power Available at MBO Microwave Study Site

Circuits	Volts	Amps	KW	Phase	Use
1	240/120	60*	15	1	6KW microwave source (via φ inverter)
2	240/120	20	5	1	Accessory power
3	120	20	2.5	1	Instrumentation
4	120	20	2.5	1	Building heat, light
5	120	30	3.6	1	1 KW microwave source

*60a^5 nominal, fused at 100 a for inverter starting load.

TABLE A4.1-1

INDIVIDUAL DATA ON STUDIES OF AVERSION/ATTRACTION TO MICROWAVE IRRADIATION

10 mW/cm^2

Bird	Trial	T°C	Pre-Exposure*					Exposure*					Post-Exposure*				
			P	S	F	E	Sh	P	S	F	E	Sh	P	S	F	E	Sh
Y32	1	21.1	81	19	0	57	43	43	57	0	68	32	76	24	0	32	68
Y32	2	20.5	79	20	1	69	30	64	36	0	73	27	53	36	11	65	24
B1	1	22.0	73	24	3	63	34	68	32	0	70	30	51	44	5	52	43
B1	2	24.4	100	0	0	20	80	69	31	0	32	68	51	49	9	42	58
R1	1	19.4	74	26	0	50	50	74	25	1	61	38	24	32	44	33	23
R1	2	19.0	37	40	23	18	59	16	69	15	33	52	10	74	16	38	46
W53	1	20.0	100	0	0	0	100	80	20	0	46	54	85	15	0	71	29
W53	2	20.6	47	53	0	25	75	45	55	0	37	63	43	57	0	30	70
Y33	1	25.0	83	17	0	36	64	72	28	0	49	51	53	39	8	62	30
Y33	2	23.3	62	36	2	40	58	61	31	8	18	74	70	29	1	40	59
Y37	1	25.0	78	15	7	62	31	58	36	6	56	48	78	17	5	59	36
Y37	2	26.6	83	13	4	25	71	73	24	3	40	57	71	27	2	50	48
O11	1	27.2	100	0	0	0	100	62	38	0	62	38	77	19	4	48	48
O11	2	28.3	72	27	0	54	46	59	41	0	43	57	50	40	0	36	64
Y36	1	24.4	56	44	0	83	17	87	8	5	80	15	53	30	17	42	42
Y36	2	25.5	39	38	23	42	35	48	19	33	40	27	41	31	28	41	31
Y35	1	24.4	89	8	3	35	62	78	19	3	55	42	62	28	10	44	42
Y35	2	24.4	53	38	9	28	63	55	37	8	43	55	55	40	5	33	62
Y34	1	22.7	52	20	28	37	35	44	48	8	49	43	39	60	1	70	29
Y34	2	24.0	37	62	1	48	51	27	45	28	37	35	10	23	67	24	10
$\bar{X}$		23.4 ±2.68	65.3	29.5	5.2	38.55	56.25	59.1	35	5.9	46.6	47.5	53.1	35.7	11.2	46.9	41.9

*The number of observations where birds were on the perch (P), side (S) and floor (F) of the cage, as well as the number of observations where birds were exposed (E) and shielded (Sh) areas of the cage.

TABLE A4.1-2

INDIVIDUAL DATA ON STUDIES OF AVERSION/ATTRACTION TO MICROWAVE IRRADIATION

25 mW/cm^2

			Pre-Exposure*					Exposure*					Post-Exposure*				
Bird	Trial	T°C	P	S	F	E	Sh	P	S	F	E	Sh	P	S	F	E	Sh
Y32	1	21.5	37	63	0	49	51	11	89	0	14	86	1	99	0	56	44
Y32	2	20.5	19	81	0	59	41	67	33	0	27	73	23	77	0	75	25
B1	1	23.5	49	46	5	54	27	47	53	0	65	29	18	82	0	49	49
B1	2	22.2	79	2	19	34	62	50	44	6	47	53	53	45	2	33	67
R1	1	23.3	70	6	24	62	14	99	1	0	1	99	25	39	36	24	40
R1	2	22.7	17	56	27	41	32	16	45	39	34	27	14	44	42	34	24
W53	1	22.7	100	0	0	4	96	95	5	0	82	18	70	30	0	51	49
W53	2	23.8	62	38	0	66	34	55	45	0	28	72	64	36	0	35	65
Y33	1	23.8	85	15	0	43	57	74	15	11	31	58	51	43	6	41	53
Y33	2	23.0	53	46	0	56	32	36	64	0	76	24	73	27	0	72	28
Y37	1	20.5	99	1	0	51	49	51	17	32	16	52	95	2	3	10	87
Y37	2	21.1	86	11	3	23	74	66	32	2	58	40	71	18	11	26	63
011	1	23.9	90	10	0	92	8	68	23	9	47	44	55	33	12	53	34
011	2	23.9	91	6	3	12	85	41	14	45	12	43	40	17	42	15	42
Y36	1	21.6	26	64	10	52	38	52	32	16	29	55	27	57	16	8	46
Y36	2	21.6	43	37	20	43	37	67	24	4	22	69	49	25	26	24	50
Y35	1	21.6	34	6	60	17	23	0	100	0	0	100	24	0	76	0	100
Y35	2	22.8	76	14	10	53	37	71	29	9	47	53	66	33	1	64	35
Y34	1	22.2	26	41	33	38	52	11	28	61	33	61	0	32	68	23	38
Y34	2	22.2	77	23	0	40	27	68	26	6	22	17	18	43	39	12	20
$\overline{X}$		22.4	61	28	11	44	44	52	34	11	35	54	42	39	19	37	48

*The number of observations where birds were on the perch (P), side (S) and floor (F) of the cage as well as the number of observations where birds were exposed (E) and shielded (Sh) areas of the cage.

TABLE A4.1-3

SUMMARY OF INDIVIDUAL DATA ON THE AVERSION/ATTRACTION EXPERIMENTS AT 50 mW/cm^2

Bird	Trial	T^{o}C	Pre-exposure*					Exposure*					Post-exposure*					RH%
			P	S	F	E	Sh	P	S	F	E	Sh	P	S	F	E	Sh	
Y32	1	18.9	16	84	0	18	82	12	83	5	9	86	24	74	2	18	78	41
Y32	2	19.4	20	80	0	74	26	20	80	0	52	48	36	64	0	95	5	69
B1	1	21.7	65	26	9	42	49	57	14	29	23	48	42	50	8	32	60	69
ΔB1	2	21.7	84	14	0	87	13	98	2	0	30	70	31	69	0	73	27	69
R1	1	20.0	18	40	42	33	25	22	18	60	20	20	57	31	12	23	71	50
R1	2	20.6	25	34	41	19	40	12	18	70	17	13	19	26	55	27	18	50
W53	1	20.6	78	22	0	42	58	93	7	0	15	85	62	38	0	50	50	39
W53	2	20.6	92	8	0	91	9	45	55	0	34	68	55	45	0	56	44	38
ΔY33	1	21.1	78	22	0	57	43	82	18	0	53	47	46	49	5	30	65	58
ΔY33	2	21.7	72	26	2	79	21	66	31	3	54	43	42	43	13	51	36	56
Y37	1	22.8	97	1	2	96	2	95	2	3	5	92	48	37	15	20	65	38
ΔY37	2	22.8	100	0	0	100	0	93	1	6	61	33	31	11	58	24	18	38
O11	1	21.1	100	0	0	8	92	71	18	11	57	32	87	8	5	28	67	43
O11	2	21.1	96	1	3	50	46	76	15	9	26	65	78	23	9	22	79	43
Y36	1	18.9	46	43	11	46	43	49	19	32	49	24	64	15	21	56	23	46
Y36	2	20.6	40	45	15	39	46	56	25	10	24	57	10	73	18	40	40	46
Y35	1	22.8	100	0	0	0	100	71	24	5	35	63	54	37	9	37	58	40
Y35	2	21.7	65	34	1	58	41	53	47	0	58	42	57	43	0	64	36	40
Y34	1	22.2	53	39	0	29	71	36	32	32	36	32	29	36	35	38	27	45
ΔY34	2	22.2	78	19	3	44	53	51	27	12	63	25	9	76	15	27	58	45
$\overline{X}$		21.1	66	27	7	50.6	43.0	58	27	5	36	49.7	44	42	14	40.5	46.2	46.7

* The number of observations in which House Finches were on the perch (P), side (S), and floor (F) of the cage, and the number of observations where birds were in exposed (E) and shielded (Sh) areas of the cage.

Δ Individuals which showed signs of thermoregulatory stress during exposure period.

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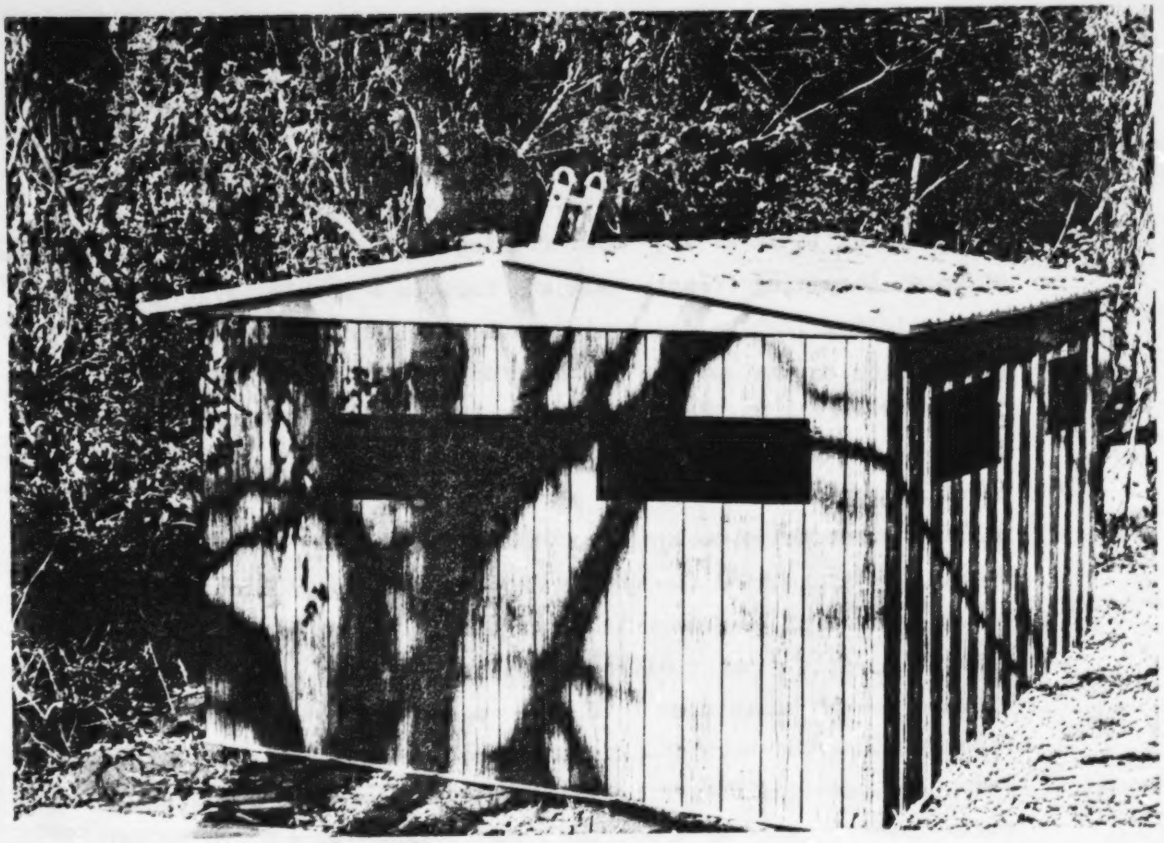

FIGURE A-1 -- PHOTOGRAPH OF MICROWAVE GENERATING AND OBSERVATION FACILITY

At the study site, sufficient space was available to construct seven cages in accordance with the dimensions specified in Reference 1. The cages were laid out in two groups, one of five cages and the second consisting of two cages. Each individual cage (Figure A-2) is four feet wide, six feet high and eight feet deep. Construction is of 2" x 3" wood framing, with sides of 3/8" CDX plywood. Screening (front, back and top) is a double layer of wire cloth, 1/2" x 1/2" welded hardware cloth on the inside and, spaced by application to the outside of the frame, 1" x 1" woven wire mesh ("chicken wire") as the outer layer. The wire covering of the cage backs is in turn covered by a double layer of 0.010" polyethylene sheet for protection from the weather. The translucent nature of the plastic sheet helps to minimize visual disturbance to the birds. The double wire screening (which was necessitated to protect the caged birds from local predators like weasels, raccoons and skunks) extends below the cages about two feet into the ground at which point it turns outward for an additional foot. The cages were enterd via a two-foot wide by four-foot high door on the front secured by barrel bolts and a lock. The panel of screening immediately adjacent to the door has no outer layer of wire mesh and the remaining hardware cloth is painted flat black. It is through this panel that the birds are observed by experimenters in the building.

A dense mat of small cedar trees has been placed at the back of each cage as well as a 0.6 x 0.6 x 0.6 meter plywood box containing a number of perches for the birds to roost on. This plywood box has a drop front which can be operated from outside the cage. To capture the birds for experimental handling, the project staff frighten the birds back into their roost box and drop the front panel. The bird can then be removed from the box via a sleeve cut into the box side. The combination of roost box and cedar trees provides excellent shelter for the inhabitants of the cages.

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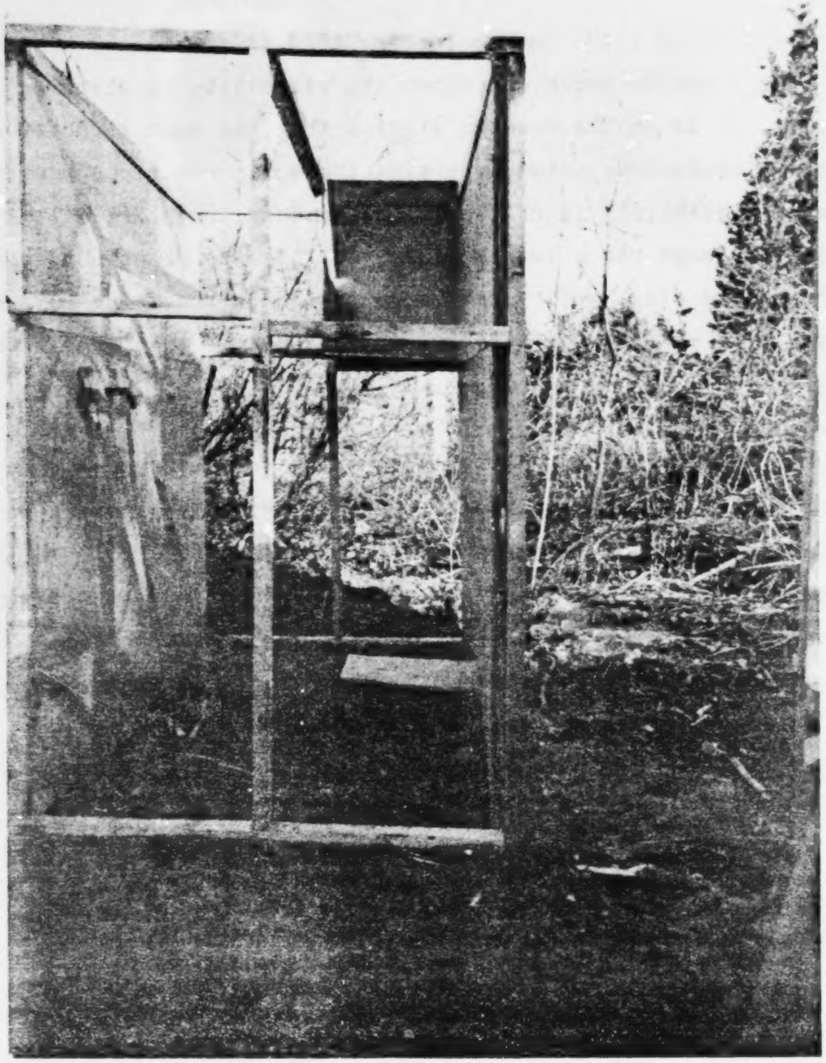

FIGURE A-2 -- PHOTOGRAPH OF FRONT VIEW OF CAGE (One of Seven)

A 44 cm (18") square feeding tray is positioned within each cage in a location which maximizes its visibility to observers in the building. It is at the feeding station that the vast majority of the interbird encounters which determine the dominance structure take place, so visibility is critical. The feeding trays are filled from outside the cage via a length of 3.8 cm (1 1/2") plastic pipe affixed to the cage's side. Water trays are located at the front of each cage, again easily visible to the observers, and are filled from outside the cage.

The design and construction of the cages is such that the experimenters are not required to enter them for any routine maintenance purpose. Food and water can be supplied from the outside, and the cedar trees which provide shelter should remain sufficiently fresh for about nine to ten months before they need to be replaced. The capture procedures occur entirely within the cage so that even if a bird escapes from the perch box or from the hand of the experimenter, it is still confined within the cage.

A4.3-2 Social Interaction Studies -- Experimental Data

This section contains data on the exposure conditions and behavioral reactions to irradiation for each of the 17 irradiated birds(*), as well as the dominance hierarchies, before and after exposure to microwaves.

Irradiation Data

Power Density: 25 mw/cm^2
Duration: 200 minutes
Cage No.: 1
Species: White-throated Sparrow
Individual(s) Irradiated: DB-DB (#3)

Date: 1/28/80
Temperature: 2°C
Cloud Cover: 5%
Wind: 12 mph from N

Observations: (irradiation time elapsed in minutes and seconds)

Settled down and moved slowly around cage, not fluffed to avoid heat loss, but neither were the controls. No behavioral change throughout irradiation.

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*The same information is included for the 3 sham controls.

Cage 1. White-throated Sparrow

*DB-DB irradiated on 1/28/80 at 25 mw/cm^2 for 200 minutes.

Total pre-irradiation observations 12/13/79-1/18/80 (525 minutes).

ACTIVE AGGRESSION

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	55	21	22	12		110
W-O	0	-	15	18	29		62
DB-DB*	0	0	-	15	7		22
LG-	0	0	0	-	20		20
Y-LB	0	0	0	1	-		1
TOTAL	0	55	36	56	68		215

AVOIDANCE

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	23	12	17	13		65
W-O	1	-	12	12	15		40
DB-DB*	0	0	-	1	1		2
LG-	0	0	0	-	11		11
Y-LB	0	0	0	0	-		0
TOTAL	1	23	24	30	40		118

Total post-irradiation observations 1/29/80 - 2/11/80 (300 minutes)

ACTIVE AGGRESSION

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	19	19	14	3		55
W-O	0	-	10	4	6		20
DB-DB*	0	0	-	14	29		43
LG-	0	0	0	-	20		20
Y-LB	13	0	0	0	-		13
TOTAL	13	19	29	32	58		151

AVOIDANCE

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	24	15	15	0		54
W-O	0	-	16	7	7		30
DB-DB*	0	0	-	6	4		10
LG-	0	0	0	-	6		6
Y-LB	3	0	0	0	-		3
TOTAL	3	24	31	28	17		103

Cage 1. White-throated Sparrow

*DB-DB irradiated on 1/28/80 at 25 mw/cm^2 for 200 minutes.

Observations immediately pre-irradiation. 30 minutes total.
1/17/80 - 1/18/80

ACTIVE AGGRESSION

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	19	4	0	0		23
W-O	0	-	6	1	0		7
DB-DB*	0	0	-	4	0		4
LG-	0	0	0	-	0		0
Y-LB	0	0	0	0	-		0
TOTAL	0	19	10	5	0		34

AVOIDANCE

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	0	4	0	0		4
W-O	0	-	5	4	0		9
DB-DB*	0	0	-	0	0		0
LG-	0	0	0	-	0		0
Y-LB	0	0	0	0	-		0
TOTAL	0	0	9	4	0		13

Observations immediately post-irradiation. 30 minutes total. 1/19/80

ACTIVE AGGRESSION

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	2	0	4	1		7
W-O	0	-	3	1	0		4
DB-DB*	0	0	-	1	0		1
LG-	0	0	0	-	7		7
Y-LB	0	0	0	0	-		0
TOTAL	0	2	3	6	8		19

AVOIDANCE

	-R	W-O	DB-DB*	LG-	Y-LB		TOTAL
-R	-	2	0	4	0		6
W-O	0	-	0	1	1		2
DB-DB*	0	0	-	0	0		0
LG-	0	0	0	-	0		0
Y-LB	0	0	0	0	-		0
TOTAL	0	2	0	5	1		8

Irradiation Data

Power Density: 25 mw/cm^2

Date: 1/24/80

Duration: 20 minutes

Temperature: -7° C.

Cage No. 2

Cloud Cover: 10%

Species: Dark-eyed Junco

Wind: 10 mph from NW

Individual(s) Irradiated: -YB (#3)

Observations: (irradiation time elapsed in minutes and seconds)

Active, similar to control birds during the 20 minutes, not fluffed in the cold weather as the White-throated Sparrows (Cage 5) were.

Cage 2. Dark-eyed Junco

* -YB irradiated on 1/24/80 at 25 mw/cm^2 for 20 minutes.

Observations immediately pre-irradiation (30 minutes total). 1/18/80

ACTIVE AGGRESSION

	-PDB	B-	*-YB	P-P	PLB-	OP-	TOTAL
-PDB	-	0	1	3	2	1	7
B-	0	-	0	2	3	0	5
-YB*	0	0	-	2	1	0	3
P-P	0	0	0	-	2	1	3
PLB-	0	0	0	0	-	0	0
OP-	0	0	0	0	0	-	0
TOTAL	0	0	1	7	8	2	18

AVOIDANCE

	-PDB	B-	*-YB	P-P	PLB-	OP-	TOTAL
-PDB	-	0	1	2	1	2	6
B-	0	-	1	1	1	0	3
-YB*	0	0	-	0	0	0	0
P-P	0	0	0	-	0	0	0
PLB-	0	0	0	0	-	0	0
OP-	0	0	0	0	0	-	0
TOTAL	0	0	2	3	2	2	9

Observations immediately post-irradiation (120 minutes total). 1/24/80

ACTIVE AGGRESSION

	-PDB	B-	*-YB	P-P	PLB-	OP-	TOTAL
-PDB	-	5	9	2	3	2	21
B-	0	-	2	2	8	1	13
-YB*	0	0	-	4	4	7	15
P-P	0	0	0	-	0	3	3
PLB-	0	0	0	0	-	1	1
OP-	0	0	0	0	0	-	0
TOTAL	0	5	11	8	15	14	53

AVOIDANCE

	-PDB	B-	*-YB	P-P	PLB-	OP-	TOTAL
-PDB	-	0	2	1	0	0	3
B-	0	-	4	1	1	6	12
-YB*	0	0	-	1	0	7	8
P-P	0	0	0	-	2	3	5
PLB-	0	0	0	0	-	1	1
OP-	0	0	0	0	0	-	0
TOTAL	0	0	6	3	3	17	29

Cage 2. Dark-eyed Junco

* -YB irradiated on 1/24/80 at 25 mw/cm^2 for 20 minutes

Total pre-irradiation observations 12/13/79 - 1/18/80 (555 minutes)

ACTIVE AGGRESSION

	-PDB	B-	-YB*	P-P	PLB-	OP-	TOTAL
-PDB	-	37	12	21	23	12	105
B-	2	-	23	27	31	31	114
-YB*	0	0	-	25	24	9	58
P-P	0	0	1	-	19	8	28
PLB-	0	0	0	1	-	19	20
OP-	0	0	0	0	1	-	1
TOTAL	2	37	36	74	98	79	326

AVOIDANCE

	-PDB	B-	-YB*	P-P	PLB-	OP-	TOTAL
-PDB	-	7	6	4	8	6	31
B-	0	-	10	8	14	7	39
-YB*	0	0	-	2	5	4	11
P-P	0	0	0	-	3	0	3
PLB-	0	0	0	1	-	5	6
OP-	0	0	0	0	0	-	0
TOTAL	0	7	16	15	30	22	90

Total post-irradiation observations 1/24/80 - 1/31/80 (330 minutes)

ACTIVE AGGRESSION

	-PDB	B-	-YB*	P-P	PLB-	OP-	TOTAL
-PDB	-	8	11	4	5	9	37
B-	0	-	10	14	21	14	59
-YB*	0	0	-	9	6	16	31
P-P	0	0	0	-	6	10	16
PLB-	0	0	0	0	-	9	9
OP-	0	0	0	0	0	-	0
TOTAL	0	8	21	27	38	58	152

AVOIDANCE

	-PDB	B-	-YB*	P-P	PLB-	OP-	TOTAL
-PDB	-	1	2	3	0	2	8
B-	0	-	5	3	9	9	26
-YB*	0	0	-	3	1	9	13
P-P	0	0	0	-	3	3	6
PLB-	0	0	1	1	-	1	3
OP-	0	0	0	0	0	-	0
TOTAL	0	1	8	10	13	24	56

Irradiation Data

Power Density:	25 mw/cm^2	Date:	1/25/80
Duration:	20 minutes	Temperature:	-6° C.
Cage No.:	3a	Cloud Cover:	0%
Species:	Dark-eyed Junco	Wind:	5 mph from NW

Individual(s) Irradiated: W-W (#4)

Observations: (irradiation time elapsed in minutes and seconds)

Active, similar to control birds during the 20 minutes, neither irradiated bird nor controls fluffed out feathers to control heat loss.

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Cage 3a. Dark-eyed Junco

*W-W irradiated on 1/25/80 at 25 mw/cm^2 for 20 minutes.

Observations immediately pre-irradiation (30 minutes total) 1/18/80.

ACTIVE AGGRESSION

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	---	2	0	0	0	0	2
-PB	0	---	1	1	7	3	12
LB-O	0	0	---	0	0	1	1
W-W*	0	0	0	---	0	1	1
R-LB	0	0	0	0	---	7	7
Y-R	0	0	0	0	0	---	0
TOTAL	0	2	1	1	7	12	23

AVOIDANCE

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	---	0	0	0	0	0	0
-PB	0	---	0	1	1	0	2
LB-O	0	0	---	0	0	0	0
W-W*	0	0	0	---	0	1	1
R-LB	0	0	0	0	---	0	0
Y-R	0	0	0	0	0	---	0
TOTAL	0	0	0	1	1	1	3

Observations immediately post-irradiation (60 minutes total) 1/29/80.

ACTIVE AGGRESSION

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	---	0	0	2	0	0	2
-PB	0	---	2	4	0	3	9
LB-O	0	0	---	4	6	3	13
W-W*	0	0	0	---	6	7	13
R-LB	0	0	0	0	---	2	2
Y-R	0	0	0	0	0	---	0
TOTAL	0	0	2	10	12	15	39

AVOIDANCE

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	---	0	2	0	1	0	3
-PB	0	---	0	3	0	0	3
LB-O	0	0	---	1	1	0	2
W-W*	0	0	0	---	2	2	4
R-LB	0	0	0	0	---	0	0
Y-R	0	0	0	0	0	---	0
TOTAL	0	0	2	4	4	2	12

Cage 3a. Dark-eyed Junco

*W-W irradiated on 1/25/80 at 25 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 1/10/80 - 1/18/80 (645 minutes)

ACTIVE AGGRESSION

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	-	5	7	12	5	10	39
-PB	1	-	26	22	42	35	126
LB-O	0	0	-	6	23	14	43
W-W*	0	1	0	-	22	27	50
R-LB	0	1	0	0	-	41	42
Y-R	0	0	0	0	0	-	0
TOTAL	1	7	33	40	92	127	300

AVOIDANCE

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	-	12	1	5	9	11	38
-PB	0	-	9	11	14	14	48
LB-O	0	0	-	2	6	7	15
W-W*	0	0	1	-	3	6	10
R-LB	0	0	1	0	-	16	17
Y-R	0	0	0	0	0	-	0
TOTAL	0	12	12	18	32	54	128

Total post-irradiation observations 1/25/80 - 2/21/80 (670 minutes)

ACTIVE AGGRESSION

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	-	8	11	7	1	-	27
-PB	0	-	18	11	14	-	43
LB-O	0	0	-	7	16	-	23
W-W*	0	0	0	-	30	-	30
R-LB	0	0	0	0	-	-	0
Y-R	-	-	-	-	-	-	
TOTAL	0	8	29	25	61		123

AVOIDANCE

	LG-DB	-PB	LB-O	W-W*	R-LB	Y-R	TOTAL
LG-DB	-	7	15	5	5	-	32
-PB	0	-	7	6	7	-	20
LB-O	1	0	-	1	5	-	7
W-W*	0	0	0	-	5	-	5
R-LB	0	0	0	0	-	-	0
Y-R	-	-	-	-	-	-	
TOTAL	1	7	22	12	22		64

Y-R died on 2/8/80.

Irradiation Data

Power Density: 25 mw/cm^2

Duration: 200 minutes

Cage No.: 4

Species: Dark-eyed Junco

Individual(s) Irradiated: Y-Y (#3)

Date: 1/30/80

Temperature: -3° C.

Cloud Cover: 5%

Wind: 2 mph from NW

Observations: (irradiation time elapsed in minutes and seconds)

0:00 not fluffed to avoid heat loss, controls slightly puffed feathers.

66:00 active, hops, not fluffed.

200:00 as above, controls slightly fluffed.

Cage 4. Dark-eyed Junco

*Y-Y irradiated on 1/30/80 at 25 mw/cm^2 for 200 minutes.

Observations immediately pre-irradiation (30 minutes total) 1/17/80-1/18/80.

ACTIVE AGGRESSION

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	0	0	1	0		1
B-Y	0	---	1	0	1		2
Y-Y*	0	0	---	1	2		3
-Y	0	0	0	---	1		1
LB-P	0	0	0	0	---		0
TOTAL	0	0	1	2	4		7

AVOIDANCE

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	0	0	0	0		0
B-Y	0	---	0	5	3		8
Y-Y*	0	0	---	0	0		0
-Y	0	0	0	---	0		0
LB-P	0	0	0	0	---		0
TOTAL	0	0	0	5	3		8

Observations immediately post-irradiation (30 minutes total) 1/30/80.

ACTIVE AGGRESSION

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	0	0	0	0		0
B-Y	0	---	5	1	0		6
Y-Y*	0	0	---	2	1		3
-Y	0	0	0	---	2		2
LB-P	0	0	0	0	---		0
TOTAL	0	0	5	3	3		11

AVOIDANCE

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	1	0	1	0		2
B-Y	0	---	0	0	0		0
Y-Y*	0	0	---	0	2		2
-Y	0	0	0	---	1		1
LB-P	0	1	0	0	---		1
TOTAL	0	2	0	1	3		6

Cage 4. Dark-eyed Junco

*Y-Y irradiated on 1/30/80 at 25 mw/cm^2 for 200 minutes.

Total pre-irradiation observations 12/13/79-1/18/80 (545 minutes).

ACTIVE AGGRESSION

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	7	13	11	6		37
B-Y	0	---	29	33	16		78
Y-Y*	0	1	---	19	20		40
-Y	0	1	1	---	28		30
LB-P	0	0	0	1	---		1
TOTAL	0	9	43	64	70		186

AVOIDANCE

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	1	1	3	9		14
B-Y	1	---	15	19	21		56
Y-Y*	0	0	---	4	2		6
-Y	0	1	0	---	5		6
LB-P	0	1	0	0	---		1
TOTAL	1	3	16	26	37		83

Total post-irradiation observations 1/30/80-2/15/80 (315 minutes).

ACTIVE AGGRESSION

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	4	10	5	3		22
B-Y	0	---	18	12	5		35
Y-Y*	0	1	---	9	14		24
-Y	0	0	0	---	20		20
LB-P	0	0	0	0	---		0
TOTAL	0	5	28	26	42		101

AVOIDANCE

	DBP-	B-Y	Y-Y*	-Y	LB-P		TOTAL
DBP-	---	6	4	6	5		21
B-Y	0	---	3	4	11		18
Y-Y*	0	0	---	7	11		18
-Y	0	0	0	---	6		6
LB-P	0	0	0	0	---		0
TOTAL	0	6	7	17	33		63

Irradiation Data

Power Density: 25 mw/cm^2

Date: 1/24/80

Duration: 20 minutes

Temperature: -7° C.

Cage No: 5

Cloud Cover: 10%

Species: White-throated Sparrows

Wind: 10 mph from NW

Individual(s) irradiated: -LB (#3)

Observations: (irradiation time elapsed in minutes and seconds)

Active, similar to control birds during the 20 minutes, the bird did not fluff up its feathers while the controls did to conserve heat.

Cage 5. White-throated Sparrow

*-LG irradiated on 1/24/80 at 25 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 12/13/79-1/18/80 (435 minutes).

ACTIVE AGGRESSION

	-W	R-R	-LG*	-WY	YLB-		TOTAL
-W	---	32	24	26	30		112
R-R	1	---	22	21	18		62
-LG*	1	2	---	33	24		60
-WY	0	0	0	---	16		16
YLB-	0	0	0	0	---		0
TOTAL	2	34	46	80	88		250

AVOIDANCE

	-W	R-R	-LG*	-WY	YLB-		TOTAL
-W	---	5	11	9	13		38
R-R	5	---	26	12	7		50
-LG*	0	0	---	6	2		8
-WY	0	0	1	---	4		5
YLB-	0	0	0	0	---		0
TOTAL	5	5	38	27	26		101

Total post-irradiation observations 1/24/80-2/4/80 (390 minutes).

ACTIVE AGGRESSION

	-W	R-R	-LG*	-WY	YLB-		TOTAL
-W	---	56	33	42	54		185
R-R	0	---	13	21	12		46
-LG*	0	0	---	11	6		17
-WY	0	0	0	---	12		12
YLB-	0	0	0	1	---		1
TOTAL	0	56	46	75	84		261

AVOIDANCE

	-W	R-R	-LG*	-WY	YLB-		TOTAL
-W	---	8	4	2	3		17
R-R	0	---	1	6	2		9
-LG*	0	0	---	2	5		7
-WY	0	0	0	---	3		3
YLB-	0	0	0	0	---		0
TOTAL	0	8	5	10	13		36

Irradiation Data

Power Density: 0 mw/cm^2 control
Date: 1/25/80
Duration: 20 minutes
Temperature: -7° C.
Cage No.: 6
Cloud Cover: 0%
Species: Dark-eyed Junco
Wind: 5 mph from NW
Individual(s) Irradiated: Y-B (#3)

Observations: (irradiation time elapsed in minutes and seconds)
Fairly active, similar to control birds during the 20 minutes, all only slightly fluffed in the cold weather.

Cage 6. Dark-eyed Junco

*Y-B irradiated on 1/25/80 at 0 mw/cm^2 for 20 minutes.

Observations immediately pre-irradiation (30 minutes total) 1/17/80-1/18/80.

ACTIVE AGGRESSION

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LC	---	1	0	1	0	0	2
-PLB	0	---	0	0	0	2	2
Y-B*	0	0	---	0	1	1	2
CS-	0	0	0	---	0	0	0
OO-	0	0	0	0	---	0	0
O-O	0	0	0	0	0	---	0
TOTAL	0	1	0	1	1	3	6

AVOIDANCE

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	0	1	0	0	1	2
-PLB	0	---	2	0	0	1	3
Y-B*	0	0	---	0	0	2	2
CS-	0	1	0	---	0	0	1
OO-	0	0	0	0	---	0	0
O-O	0	0	0	0	1	---	1
TOTAL	0	1	3	0	1	4	9

Observations immediately post-irradiation (30 minutes total) 1/25/80.

ACTIVE AGGRESSION

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	0	0	0	0	0	0
-PLB	0	---	1	0	0	1	2
Y-B*	0	0	---	3	0	0	3
CS-	0	0	0	---	0	0	0
OO-	0	0	0	0	---	0	0
O-O	0	0	0	0	0	---	0
TOTAL	0	0	1	3	0	1	5

AVOIDANCE

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	0	0	0	0	0	0
-PLB	0	---	0	0	0	0	0
Y-B*	0	0	---	2	0	1	3
CS-	0	0	0	---	0	0	0
OO-	0	0	0	0	---	0	0
O-O	0	0	0	0	0	---	0
TOTAL	0	0	0	2	0	1	3

Cage 6. Dark-eyed Junco CONTROL

*Y-B irradiated on 1/25/80 at 0 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 12/13/79-1/18/80 (580 minutes).

ACTIVE AGGRESSION

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	7	28	12	3	11	61
-PLB	2	---	39	0	9	25	75
Y-B*	0	0	---	14	18	31	63
CS-	0	9	3	---	7	6	25
OO-	0	0	0	0	---	4	4
O-O	0	0	1	0	0	---	1
TOTAL	2	16	71	26	37	77	229

AVOIDANCE

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	12	36	5	4	16	73
-PLB	2	---	5	1	2	2	12
Y-B*	1	0	---	11	10	11	33
CS-	1	3	0	---	3	4	11
OO-	0	0	0	0	---	3	3
O-O	0	0	1	0	1	---	2
TOTAL	4	15	42	17	20	36	134

Total post-irradiation observations 1/25/80-2/12/80 (405 minutes).

ACTIVE AGGRESSION

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	10	3	11	3	3	30
-PLB	0	---	17	0	17	16	50
Y-B*	0	0	---	16	9	9	34
CS-	0	18	0	---	9	7	34
OO-	0	0	0	0	---	9	9
O-O	0	0	0	0	0	---	0
TOTAL	0	28	20	27	38	44	157

AVOIDANCE

	-LG	-PLB	Y-B*	CS-	OO-	O-O	TOTAL
-LG	---	2	9	7	5	4	27
-PLB	0	---	4	0	2	3	9
Y-B*	0	1	---	14	11	12	38
CS-	0	0	0	---	0	4	13
OO-	0	0	0	2	---	2	4
O-O	0	0	0	0	0	---	0
TOTAL	0	3	13	23	27	25	91

Irradiation Data

Power Density: 25 mw/cm^2

Duration: 200 minutes

Cage No.: 7

Species: White-throated Sparrow

Individual(s) Irradiated: LB- (#3)

Date: 1/25/80

Temperature: -7° C.

Cloud Cover: 0%

Wind: 5 mph from NW

Observations: (irradiation time elapsed in minutes and seconds)

Active, similar to control birds during the 20 minutes; however, the irradiated bird did not fluff up its feathers while the control birds did to conserve heat.

Cage 7. White-throated Sparrow

*LB- irradiated on 1/25/80 at 25 mw/cm^2 for 20 minutes.

Observations immediately pre-irradiation (30 minutes total) 1/17/80-1/18/80.

ACTIVE AGGRESSION

	W-W	Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
W-W	---	2	2	0	1	3	8
Y-Y	1	---	10	4	1	3	19
-O	0	0	---	1	1	2	4
LB-*	0	0	0	---	0	2	2
-LBLG	0	0	0	0	---	2	2
-ODB	0	0	0	0	0	---	0
TOTAL	1	2	12	5	3	12	35

AVOIDANCE

	W-W	Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
W-W	---	1	0	1	0	0	2
Y-Y	0	---	2	0	3	1	6
-O	0	0	---	0	2	1	3
LB-*	0	0	0	---	1	0	1
-LBLG	0	0	0	0	---	0	0
-ODB	0	0	0	0	0	---	0
TOTAL	0	1	2	1	6	2	12

Observations immediately post-irradiation (75 minutes total) 1/25/80.

ACTIVE AGGRESSION

		Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
Y-Y		---	3	15	9	10	37
-O		0	---	4	1	1	6
LB-*		0	0	---	5	7	12
-LBLG		0	0	0	---	6	6
-ODB		0	0	0	0	---	0
TOTAL		0	3	19	15	24	61

AVOIDANCE

		Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
Y-Y		---	1	3	4	2	10
-O		0	---	2	2	1	5
LB-*		0	0	---	1	1	2
-LBLG		0	0	0	---	1	1
-ODB		0	0	0	0	---	0
TOTAL		0	1	5	7	5	18

Cage 7. White-throated Sparrow

*LB- irradiated on 1/25/80 at 25 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 12/13/80-1/18/80 (510 minutes).

ACTIVE AGGRESSION

	W-W	Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
W-W	---	24	18	7	25	15	91
Y-Y	2	---	30	17	21	21	91
-O	0	0	---	8	16	10	34
LB-*	0	0	0	---	10	6	16
-LBLG	0	0	0	0	---	12	12
-ODB	0	0	0	0	1	---	1
TOTAL	2	24	48	32	75	64	245

AVOIDANCE

	W-W	Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
W-W	---	17	8	11	14	17	67
Y-Y	1	---	6	1	11	8	27
-O	0	1	---	0	8	3	12
LB-*	0	0	0	---	2	1	3
-LBLG	0	0	0	0	---	1	1
-ODB	0	0	0	0	0	---	0
TOTAL	1	18	14	12	35	30	110

Total post-irradiation observations 1/25/80-2/6/80 (255 minutes).

ACTIVE AGGRESSION

		Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
Y-Y		---	17	27	17	31	92
-O		0	---	9	11	7	27
LB-*		0	0	---	15	40	55
-LBLG		0	0	0	---	20	20
-ODB		0	0	0	1	---	1
TOTAL		0	17	36	44	98	195

AVOIDANCE

		Y-Y	-O	LB-*	-LBLG	-ODB	TOTAL
Y-Y		---	12	12	14	8	46
-O		1	---	6	13	8	28
LB-*		0	0	---	5	3	8
-LBLG		0	0	0	---	4	4
-ODB		0	0	0	0	---	0
TOTAL		1	12	18	32	23	86

Irradiation Data

Power Density: 100 mw/cm^2	Date: 3/11/80
Duration: 20 minutes	Temperature: 4° C.
Cage No.: 1a	Cloud Cover: 95%
Species: Dark-eyed Junco	Wind: 15 mph from the NW

Individual(s) Irradiated: PG- (#2), PG-O (#4)

Observations: (irradiation time elapsed in minutes and seconds)

0:00 not fluffed to conserve heat, some hopping, beaks closed

2:00 as above but occasional gapes by PG-O

10:00 both PG-O gapes, still, PG-O closes eyes at times

14:00 PG-O blinks eyes, PG- eyes open, both sit still

16:00 as above, no gapes

20:00 as above. Control bird also shows little activity, not fluffed, no gapes

Cage 1a. Dark-eyed Junco

*PG- and PG-O irradiated on 3/11/80 at 100 mw/cm^2 for 20 minutes.

Observations immediately pre-irradiation (30 minutes total) 3/7/80.

ACTIVE AGGRESSION

	X=PGLB	PG-*	PGY	PG-O	-RDB	R-PG	TOTAL
X-PGLB	-	1	1	3	0	3	8
PG-*	0	-	0	0	0	0	0
-PGY	0	0	-	2	2	0	4
PG-O*	0	0	0	-	0	0	0
-RDB	0	1	0	0	-	1	2
R-PG	0	0	0	0	0	-	0
TOTAL	0	2	1	5	2	4	14

AVOIDANCE

	X-PGLB	PG-*	-PGY	PG-O*	-RDB	R-PG	TOTAL
X-PGLB	-	1	0	0	0	0	1
PG-*	0	-	1	0	1	1	3
-PGY	0	0	-	1	0	0	1
PG-O*	0	0	0	-	0	0	0
-RDB	0	0	0	0	-	0	0
R-PG	0	0	0	0	0	-	0
TOTAL	0	1	1	1	1	1	5

Observations immediately post-irradiation (60 minutes total) 3/11/80.

ACTIVE AGGRESSION

	X-PGLB	PG-*	PGY	PG-O	-RDB	R-PG	TOTAL
X-PGLB	-	3	7	5	3	0	18
PG-*	0	-	2	0	0	0	2
-PGY	0	0	-	2	1	1	4
PG-O*	0	0	0	-	1	0	1
-RDB	0	0	0	0	-	1	1
R-PG	0	0	0	0	0	-	0
TOTAL	0	3	9	7	5	2	26

AVOIDANCE

	X-PGLB	PG-*	-PGY	PG-O*	-RDB	R-PG	TOTAL
X-PGLB	-	0	0	1	0	0	1
PG-*	0	-	0	0	0	0	0
-PGY	0	0	-	0	1	0	1
PG-O*	0	0	0	-	0	1	1
-RDB	0	0	0	0	-	0	0
R-PG	0	0	0	0	0	-	0
TOTAL	0	0	0	1	1	1	3

Cage 1a. Dark-eyed Junco

*PG- and PG-O irradiated on 3/11/80 at 100 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 2/5/80-3/7/80 (315 minutes).

ACTIVE AGGRESSION

	X-PGLB	PG-*	-PGY	-PG-O*	-RDB	R-PG	TOTAL
X-PGLB	---	11	4	29	11	25	80
PG-*	0	---	4	16	4	7	31
-PGY	0	1	---	25	5	7	38
PG-O*	0	0	0	---	9	13	22
-RDB	0	1	0	0	---	15	16
R-PG	0	0	0	0	0	---	0
TOTAL	0	13	8	70	29	67	187

AVOIDANCE

	X-PGLB	PG-*	-PGY	-PG-O*	-RDB	R-PG	TOTAL
X-PGLB	---	4	3	3	6	5	21
PG-*	0	---	4	3	1	2	10
-PGY	0	0	---	4	4	1	9
PG-O*	0	0	0	---	5	5	10
-RDB	0	0	0	0	---	2	2
R-PG	0	0	0	0	0	---	0
TOTAL	0	4	7	10	16	15	52

Total post-irradiation observations - not yet completed.

ACTIVE AGGRESSION

	X-PGLB	PG-*	-PGY	-PG-O*	-RDB	R-PG	TOTAL
X-PGLB	---						
PG-*		---					
-PGY			---				
PG-O*				---			
-RDB					---		
R-PG						---	
TOTAL							

AVOIDANCE

	X-PGLB	PG-*	-PGY	-PG-O*	-RDB	R-PG	TOTAL
X-PGLB	---						
PG-*		---					
-PGY			---				
PG-O*				---			
-RDB					---		
R-PG						---	
TOTAL							

Irradiation Data

Power Density: 100 mw/cm^2 Date: 2/26/80
Duration: 20 minutes Temperature: -3° C.
Cage No.: 2a Cloud Cover: 30%
Species: Dark-eyed Junco Wind: 15 mph from the N
Individual(s) Irradiated: B- (#2), PLB- (#4)

Observations: (irradiation time elapsed in minutes and seconds)
0:00 sit still, little activity, beaks closed
12:00 both start occasional gapes
20:00 as above, no continued gapes, control birds fairly active also, beaks closed

Cage 2a. Dark-eyed Junco

*B- & P/LB irradiated on 2/26/80 at 100 mw/cm^2 for 20 minutes.

Observations immediately pre-irradiation (15 minutes) 2/25/80.

ACTIVE AGGRESSION

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	1	0	2	1	1	5
B-*	0	-	0	2	0	1	3
P-P	0	0	-	1	1	0	2
P/LB*	0	0	0	-	0	0	0
O/P	0	0	0	0	-	0	0
DB-R	0	0	0	0	0	-	0
TOTAL	0	1	0	5	2	2	10

AVOIDANCE

	P-DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	1	1	0	0	0	2
B-*	0	-	0	0	0	0	0
P-P	0	0	-	0	0	0	0
P/LB*	0	0	0	-	0	0	0
O/P	0	0	0	0	-	0	0
DB-R	0	0	0	0	0	-	0
TOTAL	0	1	1	0	0	0	2

Observations immediately post-irradiation (120 minutes) 2/26/80.

ACTIVE AGGRESSION

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	0	0	0	0	2	2
B-*	0	-	1	2	0	1	4
P-P	0	0	-	4	1	3	8
P/LB*	0	0	0	-	2	2	4
O/P	0	0	1	0	-	5	6
DB-R	0	0	0	0	0	-	0
TOTAL	0	0	2	6	3	13	24

AVOIDANCE

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	0	7	1	0	3	11
B-*	0	-	3	2	0	0	5
P-P	0	0	-	2	0	2	4
P/LB*	0	0	0	-	0	3	3
O/P	0	0	0	0	-	0	0
DB-R	0	0	0	0	0	-	0
TOTAL	0	0	10	5	0	8	23

Cage 2a. Dark-eyed Junco

*B- & P/LB irradiated on 2/26/80 at 100 mw/cm^2 for 20 minutes.

Total observations pre-irradiation from 2/6/80 - 2/26/80 for 465 minutes.

ACTIVE AGGRESSION

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	11	5	11	11	9	47
B-*	1	-	8	8	22	10	49
P-P	0	0	-	16	21	7	44
P/LB*	0	0	0	-	29	22	51
O/P	0	0	0	0	-	29	29
DB-R	0	0	0	0	0	-	0
TOTAL	1	11	13	35	83	77	220

AVOIDANCE

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	6	8	8	7	6	35
B-*	0	-	12	12	15	5	44
P-P	0	0	-	6	5	3	14
P/LB*	0	0	0	-	6	3	9
O/P	0	0	0	0	-	4	4
DB-R	0	0	0	0	0	-	0
TOTAL	0	6	20	26	33	21	106

Total observations post-irradiation from 2/26/80 - 3/10/80 for 445 minutes.

ACTIVE AGGRESSION

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	5	8	5	8	8	34
B-*	0	-	9	7	18	9	43
P-P	0	0	-	15	9	7	31
P/LB*	0	0	0	-	25	20	45
O/P	0	0	1	0	-	24	25
DB-R	0	0	0	0	0	-	0
TOTAL	0	5	18	27	60	68	178

AVOIDANCE

	P/DB	B-*	P-P	P/LB*	O/P	DB-R	TOTAL
P/DB	-	2	17	4	7	5	35
B-*	0	-	7	6	9	7	29
P-P	0	0	-	13	3	5	21
P/LB*	0	0	0	-	5	5	10
O/P	0	0	1	0	-	3	4
DB-R	0	0	0	0	0	-	0
TOTAL	0	2	25	23	24	25	99

Irradiation Data

Power Density: 0 mw/cm^2 CONTROL

Date: 3/11/80

Duration: 20 minutes

Temperature: 3° C.

Cage No.: 3b

Cloud Cover: 20%

Species: Dark-eyed Junco

Wind: 15 mph from the NW

Individual(s) Irradiated: -LG (#2), -PLB

Observations: (irradiation time elapsed in minutes and seconds)

0:00 no activity, beaks closed, feathers not fluffed.

4:00 as above but slightly fluffed. Controls the same.

10:00 control birds attacked by American Kestrel, driven off by observer.

20:00 no change, all birds were slightly fluffed, beaks closed.

Cage 3b. Dark-eyed Junco CONTROL

*-LG and PLB- irradiated on 3/11/80 at 0 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 2/22/80 - 3/7/80 (330 minutes)

ACTIVE AGGRESSION

	B-Y	-LG*	CS-	PLB-*	DBP-	-Y	TOTAL
B-Y	-	12	13	8	4	22	59
-LG*	1	-	8	5	11	17	42
CS-	0	0	-	14	13	17	44
PLB-*	1	0	0	-	9	22	32
DBP-	8	1	0	0	-	9	18
-Y	0	0	0	1	0	-	1
TOTAL	10	13	21	28	37	87	196

AVOIDANCE

	B-Y	-LG*	CS-	PLB-*	DBP-	-Y	TOTAL
B-Y	-	3	5	0	1	1	10
-LG*	0	-	8	4	3	6	21
CS-	1	0	-	2	5	7	15
PLB-*	0	0	0	-	2	4	6
DBP-	9	0	0	0	-	6	15
-Y	0	0	0	0	0	-	0
TOTAL	10	3	13	6	11	24	67

Total post-irradiation observations 3/11/80 - 3/20/80 (300 minutes).

ACTIVE AGGRESSION

	B-Y	-LG*	CS-	PLB-*	DBP-	-Y	TOTAL
B-Y	-	6	12	5	0	23	46
-LG*	0	-	15	8	7	13	43
CS-	0	0	-	10	12	16	38
PLB-*	0	0	0	-	5	21	26
DBP-	4	0	1	0	-	10	15
-Y	0	0	0	0	1	-	1
TOTAL	4	6	28	23	25	83	169

AVOIDANCE

	B-Y	-LG*	CS-	PLB-*	DBP-	-Y	TOTAL
B-Y	-	1	9	2	0	9	21
-LG*	0	-	5	1	2	12	20
CS-	0	0	-	5	5	15	25
PLB*	0	0	0	-	0	2	2
DBP-	4	0	0	0	-	3	7
-Y	0	0	0	0	0	-	0
TOTAL	4	1	14	8	7	41	75

Irradiation Data

Power Density: 100 mw/cm^2 Date: 3/11/80

Duration: 20 minutes Temperature: 4° C.

Cage No.: 4a Cloud Cover: 100%

Species: Dark-eyed Junco Wind: 15 mph from the NW

Individual(s) Irradiated: DBY-DBW (#2), R-LB (#4)

Observations: (irradiation time elapsed in minutes and seconds)

0:00 sit still, not fluffed feathers
5:00 as above, R-LB gapes several times, DBY-DBW not
7:00 R-LB frequently gapes, DBY-DBW does so occasionally
14:00 R-LB still, constantly gapes, DBY-DBW occasional gapes, hops
18:00 both still with occasional gapes
20:00 as above, controls hop without fluffed feathers

Cage 4a. Dark-eyed Junco

*DBY- and R-LB irradiated on 3/11/80 at 100 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 2/25/80 - 3/10/80 (315 minutes)

ACTIVE AGGRESSION

	Y-CS	DBY-*	OO-	R-LB*	OO-	YR-	TOTAL
Y-CS	-	16	4	18	16	10	64
DBY-*	0	-	14	15	16	7	52
OO-	1	0	-	15	15	10	37
R-LB*	0	0	0	-	26	18	44
O-O	0	0	0	0	-	17	17
YR-	0	0	0	0	0	-	0
TOTAL	1	16	18	44	73	62	224

AVOIDANCE

	YCS	DBY-*	OO-	R-LB*	O-O	YR-	TOTAL
Y-CS	-	5	1	4	4	2	16
DBY-*	0	-	2	5	7	2	16
OO-	2	0	-	3	3	1	9
R-LB*	0	0	0	-	6	3	9
O-O	0	1	0	0	-	1	2
YR-	0	0	0	0	0	-	0
TOTAL	2	6	3	12	20	9	52

Total post-irradiation observations 3/11/80 - 3/20/80 (315 minutes)

ACTIVE AGGRESSION

	Y-CS	DBY-*	OO-	R-LB*	O-O	YR-	TOTAL
Y-CS	-	9	1	26	14	17	67
DBY-*	0	-	18	18	10	7	53
OO-	3	1	-	10	18	7	39
R-LB*	0	0	0	-	28	25	53
O-O	0	0	0	0	-	23	23
YR-	0	0	0	0	0	-	0
TOTAL	3	10	19	54	70	79	235

AVOIDANCE

	YCS	DBY-*	OO-	R-LB*	O-O	YR-	TOTAL
Y-CS	-	2	0	5	10	1	18
DBY-*	0	-	1	5	6	5	17
OO-	3	1	-	8	9	2	23
R-LB*	0	0	0	-	7	4	11
O-O	0	0	0	0	-	3	3
YR-	0	0	0	0	0	-	0
TOTAL	3	3	1	18	32	15	72

Irradiation Data

Power Density: 100 mw/cm^2

Duration: 20 minutes

Cage No.: 5a

Species: Dark-eyed Junco

Individual(s) Irradiated: OB- (#3)

Date: 2/19/80

Temperature: 6° C.

Cloud Cover: 10%

Wind: 0

Observations: (irradiation time elapsed in minutes and seconds)

5:00 still with little movement from start of irradiation, feathers not fluffed, starts to gape now

15:00 stands still with beak opening frequently

18:00 as above, beak open continuously

20:00 as above, control birds did not gape, feathers not fluffed.

Cage 5a. Dark-eyed Junco

*OB irradiated on 2/19/80 at 100 mw/cm² for 20 minutes.

Observations immediately pre-irradiation (60 minutes total) 2/19/80.

ACTIVE AGGRESSION

	-DB	Y-O	OB*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	---	2	3	3	3	3	14
Y-O	0	---	0	0	1	1	2
OB-*	0	0	---	1	1	4	6
CS-CS	0	0	0	---	1	0	1
LG-P	0	0	0	0	---	4	4
RLB-RLB	0	0	0	0	0	---	0
TOTAL	0	2	3	4	6	12	27

AVOIDANCE

	-DB	Y-O	OB*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	---	3	2	2	2	2	11
Y-O	0	---	2	0	0	1	3
OB-*	0	0	---	0	1	2	3
CS-CS	0	0	0	---	0	0	0
LG-P	0	0	0	0	---	0	0
RLB-RLB	0	0	0	0	0	---	0
TOTAL	0	3	4	2	3	5	17

Observations immediately post-irradiation (60 minutes total) 2/19/80.

ACTIVE AGGRESSION

	-DB	Y-O	OB*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	---	0	0	0	0	1	1
Y-O	0	---	3	0	0	3	6
OB-*	0	0	---	0	0	1	1
CS-CS	0	0	0	---	0	0	0
LG-P	0	0	0	0	---	0	0
RLB-RLB	0	0	0	0	0	---	0
TOTAL	0	0	3	0	0	5	8

AVOIDANCE

	-DB	Y-O	OB*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	---	1	1	1	0	0	3
Y-O	0	---	0	0	0	2	2
OB-*	0	0	---	0	0	0	0
CS-CS	0	0	0	---	0	0	0
LG-P	0	0	0	0	---	0	0
RLB-RLB	0	0	0	0	0	---	0
TOTAL	0	1	1	1	0	2	5

Cage 5a. Dark-eyed Junco

*O/B- irradiated on 2/19/80 at 100 mw/cm^2 for 20 minutes.

Total pre-irradiation observations 2/6/80 - 2/19/80 (390 minutes).

ACTIVE AGGRESSION

	-DB	Y-O	OB-*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	-	17	16	16	7	29	85
Y-O	0	-	5	5	10	17	37
OB-*	0	0	-	4	6	19	29
CS-CS	0	0	0	-	10	4	14
LG-P	0	0	0	0	-	18	18
RLB-RLB	0	0	0	0	0	-	0
TOTAL	0	17	21	25	33	87	183

AVOIDANCE

	-DB	Y-O	OB-*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	-	18	17	6	11	11	63
Y-O	1	-	8	0	4	7	20
OB-*	0	0	-	5	7	9	21
CS-CS	0	0	0	-	4	4	8
LG-P	0	0	0	1	-	3	4
RLB-RLB	0	0	0	1	0	-	1
TOTAL	1	18	25	13	26	34	117

Total post-irradiation observations 2/19/80-3/7/80 (435 minutes).

ACTIVE AGGRESSION

	-DB	Y-O	OB-*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	-	17	6	7	9	18	57
Y-O	0	-	21	8	9	22	60
OB-*	0	0	-	9	7	14	30
CS-CS	0	0	0	-	7	10	17
LG-P	0	0	0	0	-	27	27
RLB-RLB	0	0	0	0	0	-	0
TOTAL	0	17	27	24	32	91	191

AVOIDANCE

	-DB	Y-O	OB-*	CS-CS	LG-P	RLB-RLB	TOTAL
-DB	-	14	4	4	6	3	31
Y-O	0	-	11	6	12	6	35
OB-*	0	1	-	4	3	2	10
CS-CS	0	0	0	-	5	4	9
LG-P	0	0	0	0	-	1	1
RLB-RLB	0	0	0	0	0	-	0
TOTAL	0	15	15	14	26	16	86

Irradiation Data

Power Density: 155 mw/cm^2

Duration: 10 minutes

Cage No.: 6a

Species: Dark-eyed Junco

Individual(s) Irradiated: -PB (#2), LB-O (#4)

Date: 3/17/80

Temperature: 13° C.

Cloud Cover: 70%

Wind: 5 mph from the S

Observations: (irradiation time elapsed in minutes and seconds)

0:00 hop and sit still, beaks closed, feathers not fluffed.

2:00 both gape constantly, as above otherwise.

5:00 constantly gape, LB-O hops constantly, -PB sits still.

7:00 -PB stands, constant gape and pants visibly. LB-O falls on back, quivers wings and tail for 30 seconds, then dies.

9:00 -PB hops and stands, gapes constantly.

10:00 as above, -PB survives. This bird had perfect plumage, while the dead LB-O had lost crown feathers, possibly increasing heat uptake on the head? Control birds hopped and sat, beaks closed throughout.

Cage 6a. Dark-eyed Junco

*-PB and LB-O irradiated on 3/17/80 at 155 mw/cm^2 for 10 minutes.

Observations immediately pre-irradiation (30 minutes total) 3/14/80-3/17/80.

ACTIVE AGGRESSION

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---	1	0	0	2	3	6
-PB*	0	---	1	2	0	3	6
W-	0	0	---	1	0	0	1
LB-O*	0	0	0	---	0	1	1
LB-P	0	0	0	0	---	1	1
O-LG	0	0	0	0	0	---	0
TOTAL	0	1	1	3	2	8	15

AVOIDANCE

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---	1	0	0	1	0	2
-PB*	0	---	0	0	0	0	0
W-	0	0	---	0	0	0	0
LB-O*	0	0	0	---	0	0	0
LB-P	0	0	0	0	---	0	0
O-LG	0	1	0	0	1	---	2
TOTAL	0	2	0	0	2	0	4

ACTIVE AGGRESSION

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---	0	0		1	2	3
-PB*	0	---	0		1	0	1
W-	0	0	---		0	3	3
LG-O*	---	---	---	---	---	---	---
LB-P	0	0	0		---	4	4
O-LG	0	0	0		0	---	0
TOTAL	0	0	0		2	9	11

AVOIDANCE

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---	1	0		0	0	1
-PB	0	---	0		1	0	1
W-	2	0	---		0	0	2
LG-O*	---	---	---	---	---	---	---
LB-P	0	0	0		---	0	0
O-LG	0	0	0		0	---	0
TOTAL	2	1	0		1	0	4

Cage 6a. Dark-eyed Junco

*-PB and LB-O irradiated on 3/17/80 at 155 mw/cm^2 for 10 minutes.

Total pre-irradiation observations 2/25/80-3/15/80 (360 minutes).

ACTIVE AGGRESSION

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---	16	0	13	6	6	41
-PB*	0	---	11	16	30	12	69
W-	6	0	---	8	11	9	34
LB-O*	0	0	0	---	14	8	22
LB-P	0	0	0	0	---	24	24
O-LG	0	0	0	0	0	---	0
TOTAL	6	16	11	37	61	59	190

AVOIDANCE

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---	4	0	4	6	2	16
-PB*	0	---	0	1	4	2	7
W-	2	0	---	3	3	1	9
LB-O*	0	0	0	---	4	0	4
LB-P	0	0	0	0	---	0	0
O-LG	0	0	0	0	0	---	0
TOTAL	2	4	0	8	17	5	36

Total post-irradiation observations - not yet complete.

ACTIVE AGGRESSION

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---						
-PB*		---					
W-			---				
LB-O*				---			
LB-P					---		
O-LG						---	
TOTAL							

AVOIDANCE

	LG-DB	-PB*	W-	LB-O*	LB-P	O-LG	TOTAL
LG-DB	---						
-PB*		---					
W-			---				
LB-O*				---			
LB-P					---		
O-LG						---	
TOTAL							

Irradiation Data

Power Density: 155 mw/cm^2
Duration: 7 minutes
Cage No.: 7a
Species: Dark-eyed Junco

Date: 3/17/80
Temperature: 13° C.
Cloud Cover: 100%
Wind: 5 mph from the S

Individual(s) Irradiated: PG-PG (#3), CS-LG (#5)

Observations: (irradiation time elapsed in minutes and seconds)

0:00 both hop and sit still, beaks closed, feathers not fluffed.

2:00 some activity, mostly still, gape beaks.

4:00 as above.

5:00 CS-LG as above, PG-PG falls forward, defecates frequently, not active but alive.

7:00 CS-LG as above, PG-PG falls over on head, quivers wings and tail and dies in seconds. Controls sit still, beaks closed. CS-LG had perfect plumage, PG-PG a healing scrape on the crown, possibly increasing heat uptake on the head?

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Cage 7a. Dark-eyed Junco

*PG-PG and CS-LG irradiated on 3/17/80 at 155 mw/cm^2 for 7 minutes.

Observations immediately pre-irradiation (30 minutes total) 3/15/80-3/17/80.

ACTIVE AGGRESSION

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---	0	0	1	0	1	2
W-PGW	0	---	2	2	1	3	8
PG-PG*	0	0	---	0	0	4	4
PG/PG-	0	0	0	---	1	1	2
CS-LG*	0	0	0	0	---	2	2
RO-RY	0	0	0	0	0	---	0
TOTAL	0	0	2	3	2	11	18

AVOIDANCE

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---	2	0	0	0	0	2
W-PGW	0	---	2	1	0	1	4
PG-PG*	0	0	---	0	0	1	1
PG/PG-	0	0	0	---	0	0	0
CS-LG*	0	0	0	0	---	0	0
RO-RY	0	0	0	0	0	---	0
TOTAL	0	2	2	1	0	2	7

Observations immediately post-irradiation (45 minutes total) 3/17/80.

ACTIVE AGGRESSION

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---	1		0	0	0	1
W-PWG	0	---		0	0	0	0
PG-PG*	---	---	---	---	---	---	---
PG/PG-	0	0		---	0	0	0
CS-LG*	0	0		0	---	0	0
RO-RY	0	0		0	0	---	0
TOTAL	0	1		0	0	0	1

AVOIDANCE

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---	0		0	0	0	0
W-PGW	0	---		0	0	0	0
PG-PG*	---	---	---	---	---	---	---
PG/PG-	0	0		---	0	0	0
CS-LG*	0	0		0	---	0	0
RO-RY	0	0		0	0	---	0
TOTAL	0	0		0	0	0	0

Cage 7a. Dark-eyed Junco

*PG-PG and CS-LG irradiated on 3/17/80 at 155 mw/cm^2 for 7 minutes.

Total observations pre-irradiation 2/11/80-3/17/80 (470 minutes).

ACTIVE AGGRESSION

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---	16	20	17	3	15	71
W-PGW	0	---	20	15	4	13	52
PG-PG*	0	0	---	10	3	12	25
PG/PG-	0	0	0	---	4	9	13
CS-LG*	0	0	0	0	---	11	11
RO-RY	0	0	0	1	0	---	1
TOTAL	0	16	40	43	14	60	173

AVOIDANCE

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---	5	1	7	0	3	16
W-PGW	1	---	4	2	0	3	10
PG-PG*	0	0	---	5	0	2	7
PG/PG-	0	0	0	---	0	1	1
CS-LG*	0	0	0	0	---	2	2
RO-RY	0	0	1	0	0	---	1
TOTAL	1	5	6	14	0	11	37

Total observations post-irradiation - not yet completed.

ACTIVE AGGRESSION

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---						
W-PGW		---					
PG-PG*			---				
PG/PG-				---			
CS-LG*					---		
RO-RY						---	
TOTAL							

AVOIDANCE

	R-O	W-PGW	PG-PG*	PG/PG-	CS-LG*	RO-RY	TOTAL
R-O	---						
W-PGW		---					
PG-PG*			---				
PG/PG-				---			
CS-LG*					---		
RO-RY						---	
TOTAL							

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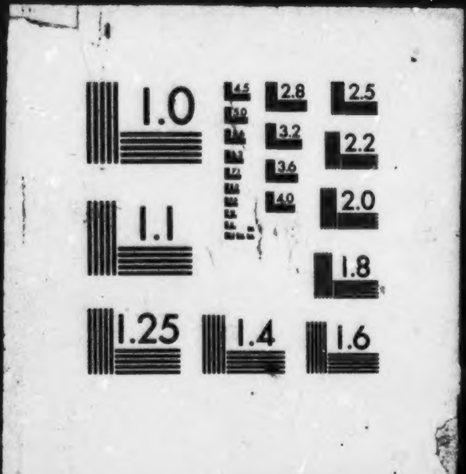
A-3. Lethal Dose Experiment

This section contains the exposure conditions and response of the 8 birds receiving microwave irradiation at or near lethal levels.

5 OF 5
PB 84
141191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Experiment Identification: (a)
Power Density: 160 mw/cm^2
Species: Dark-eyed Junco

Date: 3/24/80
Temperature: 11°C.
Cloud Cover: 10%
Wind: 0

Post irradiation cloacal temperature 42.3°C. (bird died)

Observations: (elapsed irradiation time in minutes and seconds)

0:00 constantly hopping, beak closed.
0:30 as above, frequently gapes.
4:30 hops more slowly, stumbles and gapes constantly.
5:30 sits, chirps, gapes constantly.
6:00 as above, panting visibly, eyes remain open.
6:30 lying down
6:50 rapidly quivers, evacuates feces, chirps, dies, cloaca not everted.

A superficial post-mortem showed no obvious abnormalities; the bird was a male.

Experiment Identification: (b)
Date: 3/24/80
Power Density: 160 mw/cm^2
Temperature: 9°C.
Species: Dark-eyed Junco
Cloud Cover: 30%
Wind: 0

Pre-irradiation cloacal temperature 36.0°C.
Post-irradiation cloacal temperature 42.2°C. (bird died)

Observations: (elapsed irradiation time in minutes and seconds)

0:00 constantly hopping, beak closed.
0:25 as above, frequently gapes.
1:00 as above, constantly gapes.
3:00 as above, but rate of hopping slows.
4:00 little hopping, rocks when standing, constantly gapes.
5:00 stands still, gapes and pants.
5:30 sits, gapes, pants, eyes remain open.
6:10 rapidly quivers, evacuates feces, dies with partly everted cloaca.

A superficial post-mortem showed no obvious abnormalities; the bird was a male and had three large nematodes in the abdominal cavity.

Experiment Identification: (c) Date: 3/23/80

Power Density: 128 mw/cm^2 Temperature: 9°C.

Species: Dark-eyed Junco Cloud Cover: 60%

Wind: 0

Pre-irradiation cloacal temperature 37.9°C.

Post-irradiation cloacal temperature 38.6°C. (bird survived)

Observations: (elapsed irradiation time in minutes and seconds)

0:00 rapid constant hopping, chirps, beak closed.

2:00 constantly hopping, starts occasional gapes.

3:00 as above, gapes 50% of the time.

3:30 as above, constant wide gapes.

8:00 as above, hops more slowly.

14:00 wide gapes, hops and stands still.

17:00 bird turned head to observe a Common Grackle with flew overhead.

20:00 as above. No evacuation of feces, eyes remained open. Beak closed when irradiation ceased.

Five minutes after release the bird drank from its water dish. No behavioral anomalies noted in the subsequent two days, observations continue.

Experiment Identification: (d) Date: 3/24/80

Power Density: 128 mw/cm^2 Temperature: 7°C.

Species: Dark-eyed Junco Cloud Cover: 80%

Wind: 0

(Bird survives)

Observations: (elapsed irradiation time in minutes and seconds)

0:00 constantly hopping, beak closed.
1:30 as above.
2:00 frequently gapes, chirps, hops,
12:00 as above, no change except gapes constantly.
13:30 as above, hops more slowly.
17:30 as above, stands still.
20:00 no change, no evacuation of feces, eyes remained open, beak closed when irradiation ceased.

On release the bird went into cover at the rear of the cage. No behavioral anomalies noted in the subsequent two days, observations continue.

TABLE A4.4-1

CLOACAL TEMPERATURES (^{o}C) OF NINE HOUSE FINCHES MONITORED FOR EIGHTEEN MINUTES

WITHOUT IRRADIATION

MINUTES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIRD																			
Y32	42.5	42.6	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.6	42.6	42.6	42.5	42.5	42.5	42.5	42.5
W53	42.6	42.7	42.9	42.9	43.0	43.0	43.0	42.9	42.9	43.8	42.9	43.0	43.0	43.0	43.0	42.9	42.9	43.0	43.0
Y34	41.6	41.6	41.6	41.6	41.6	41.5	41.4	41.4	41.2	41.2	41.1	41.2	41.3	41.3	41.3	41.3	41.3	41.2	41.2
O11	42.0	41.9	41.8	41.7	41.6	41.6	41.4	41.3	41.2	41.2	41.1	41.1	41.0	41.0	41.0	41.0	41.0	41.0	41.0
Y35	42.7	42.8	43.0	43.0	43.0	43.0	43.0	43.0	43.0	42.9	42.9	43.0	42.9	42.9	42.8	42.8	42.8	42.8	42.8
B1	42.1	42.1	42.2	42.2	42.3	42.4	42.4	42.4	42.4	42.3	42.3	42.4	42.3	42.3	42.3	42.3	42.3	42.2	42.1
Y36	42.9	43.0	43.0	43.0	42.9	42.9	43.0	42.9	42.8	42.7	42.6	42.4	42.2	42.1	42.0	41.9	41.6	41.5	41.4
Y37	42.4	42.6	42.6	42.6	42.6	42.6	42.5	42.5	42.4	42.4	42.3	42.3	42.3	42.2	42.2	42.2	42.2	42.2	42.3
R1	42.7	42.9	43.1	43.1	42.9	42.4	42.3	42.4	42.5	42.5	42.5	42.5	42.6	42.5	42.6	42.6	42.6	42.6	42.6
$\overline{X}$	42.4	42.5	42.7	42.5	42.5	42.5	42.4	42.4	42.3	42.3	42.3	42.3	42.2	42.2	42.2	42.2	42.1	42.1	42.1
SD	.41	.48	.67	.59	.56	.56	.63	.63	.63	.67	.70	.69	.68	.68	.67	.66	.68	.72	.73

TABLE A4.4-2

CLOACAL TEMPERATURES (°C) OF TEN HOUSE FINCHES IRRADIATED* WITH 25 mW/cm^2 ORIENTED PERPENDICULAR TO THE E VECTOR OF THE MICROWAVE FIELD FOR TEN MINUTES

MINUTES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIRD																			
Y32	40.9	40.9	40.8	40.8	41.0	41.2	41.4	41.5	41.5	41.5	41.6	41.6	41.6	41.6	41.5	41.3	41.1	40.9	40.9
Y34	41.2	41.6	41.7	41.7	42.1	42.3	42.3	42.6	42.7	42.6	42.6	42.5	42.5	42.4	41.9	41.6	41.4	41.3	41.2
O11	41.4	41.3	41.3	41.2	41.7	41.9	42.1	42.1	42.0	41.9	41.8	41.7	41.6	41.6	41.3	41.1	40.9	40.9	40.8
R1	42.0	41.7	41.4	41.2	41.3	41.3	41.2	41.1	40.8	40.6	40.5	40.3	40.2	40.2	39.9	40.0	40.1	40.2	40.2
Y36	42.0	42.0	42.0	42.0	42.3	42.4	42.3	42.2	42.2	42.1	42.0	41.8	41.8	41.7	41.4	41.1	40.9	41.0	40.6
Y37	40.6	40.6	40.6	40.5	40.7	40.9	41.0	41.0	41.1	41.2	41.3	41.2	41.1	41.1	41.0	41.0	41.0	40.8	40.8
R1	41.3	41.4	41.4	41.5	41.7	41.8	41.9	41.8	41.8	41.8	41.8	41.8	41.8	41.8	42.5	42.5	42.4	42.2	42.1
Y33	42.5	42.5	42.5	42.6	42.8	42.8	42.5	42.5	42.4	42.0	41.9	41.8	41.7	41.7	41.4	41.1	40.8	40.7	40.6
O-G	41.9	41.9	41.9	41.9	42.3	42.5	42.6	42.6	42.5	42.5	42.2	42.0	41.8	41.7	41.4	41.2	40.9	40.8	40.8
CS-W	40.9	40.8	41.2	41.3	41.4	41.4	41.1	40.9	40.7	40.3	39.9	39.7	39.6	39.5	39.1	39.0	30.2	38.8	38.7
$\bar{X}$	41.5	41.5	41.5	41.5	41.7	41.8	41.8	41.8	41.8	41.6	41.6	41.4	41.4	41.3	41.1	41.0	40.9	40.8	40.7
SD	.61	.59	.57	.61	.65	.64	.61	.67	.72	.76	.81	.84	.86	.86	.97	.93	.82	.93	.85

*Exposure period begins at minute three and ends at minute thirteen.

TABLE A4.4-3

CLOACAL TEMPERATURES (°C) OF TEN HOUSE FINCHES IRRADIATED* WITH 25 mW/cm^2 ORIENTED PARALLEL TO THE E VECTOR OF THE MICROWAVE FIELD FOR TEN MINUTES

MINUTES BIRD	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Y32	42.3	42.1	42.0	42.0	42.2	42.3	42.3	42.3	42.2	42.1	42.1	42.1	42.1	42.1	41.7	41.6	41.5	41.5	41.5
Y34	42.2	42.2	42.2	42.2	42.4	42.6	42.8	42.9	42.9	42.9	42.8	42.7	42.6	42.5	42.2	41.9	41.5	41.3	41.2
O11	42.2	42.1	42.0	42.0	42.3	42.6	42.7	42.8	42.7	42.6	42.5	42.5	42.4	42.3	41.9	41.6	41.4	41.3	41.3
B1	42.3	42.2	42.2	42.1	42.4	42.6	42.7	42.8	42.9	42.9	42.8	42.8	42.9	42.8	42.7	42.5	41.9	41.7	41.3
Y33	42.5	42.3	42.1	42.1	42.4	42.7	42.9	42.9	42.6	42.5	42.3	42.2	42.2	42.1	41.6	41.3	40.8	40.4	—
Y36	42.2	42.1	42.1	42.1	42.3	42.4	42.4	42.4	42.5	42.6	42.7	42.3	42.2	42.1	41.8	41.4	41.0	40.6	40.3
Y37	42.2	42.3	42.4	42.4	42.7	42.8	42.9	42.9	42.8	42.8	42.7	42.7	42.6	42.6	42.4	42.2	42.1	42.1	42.0
R1	42.2	42.2	42.2	42.2	42.5	42.7	42.8	42.8	42.8	42.8	42.9	43.0	42.9	43.0	42.6	42.1	41.7	41.3	--
O-G	42.1	42.0	41.9	41.8	41.4	41.7	41.7	41.8	41.9	41.8	41.8	41.7	41.0	41.1	41.0	40.9	40.6	40.2	39.8
CS-W	42.5	42.4	42.2	42.1	42.3	42.4	42.5	42.4	42.5	42.5	42.6	42.5	42.5	42.5	42.0	41.6	41.4	41.7	41.0
$\overline{X}$	42.3	42.2	42.1	42.1	42.3	42.5	42.6	42.6	42.6	42.5	42.5	42.4	42.3	42.3	42.0	41.7	41.4	41.2	41.0
SD	.13	.12	.14	.16	.34	.32	.37	.37	.32	.36	.35	.38	.55	.52	.51	.47	.47	.62	.69

*Exposure period begins at minute three and ends at minute thirteen.

-- Probe dislodged from cloaca before termination of the observation period; no temperatures recorded.

TABLE A4.4-4

CLOACAL TEMPERATURES (°C) OF TEN HOUSE FINCHES IRRADIATED* WITH 50 mW/cm^2 ORIENTED PERPENDICULAR TO THE E VECTOR OF THE MICROWAVE FIELD FOR TEN MINUTES

MINUTES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIRD																			
Y32	43.1	43.1	42.9	42.9	43.3	43.4	43.5	43.5	43.6	43.7	43.7	43.7	43.8	43.9	43.5	43.0	42.7	42.6	42.5
W53	42.4	42.2	42.2	42.2	42.6	42.8	42.9	43.0	43.1	43.2	43.2	43.3	43.5	43.6	43.2	42.8	42.2	42.2	42.1
Y34	43.0	43.0	43.0	43.0	43.4	43.6	43.7	43.8	43.8	43.8	43.8	43.9	43.9	43.9	43.5	43.0	42.5	42.0	41.7
O11	41.4	41.4	41.4	41.5	42.0	42.2	42.5	42.6	42.7	42.9	43.0	43.3	43.4	43.3	42.9	42.5	42.1	41.6	41.2
Y35	42.0	41.9	41.9	42.0	42.4	42.6	42.7	42.9	43.0	43.1	43.1	43.3	43.0	42.9	42.5	42.1	41.7	41.4	41.0
B1	43.2	43.2	43.1	43.0	43.5	43.8	43.9	44.0	44.2	44.4	44.7	44.8	44.8	44.9	44.5	44.0	43.5	43.0	42.7
Y33	42.1	42.4	42.4	42.4	42.7	43.0	43.2	43.4	43.5	43.7	43.9	44.3	44.5	44.7	44.3	43.9	43.4	43.0	42.5
Y36	42.6	42.5	42.4	42.4	42.9	43.1	43.1	43.1	43.1	43.1	43.1	43.2	43.4	43.5	43.0	42.7	42.5	42.4	42.4
Y37	42.4	42.5	42.5	42.5	42.9	42.9	43.0	43.2	43.2	43.3	43.4	43.4	43.5	43.5	43.1	42.9	42.7	42.5	42.5
R1	42.0	41.9	41.7	41.7	42.2	42.4	42.5	42.6	42.8	42.9	43.1	43.3	43.3	43.8	43.4	42.9	42.5	42.1	41.6
$\bar{X}$	42.4	42.1	42.3	42.4	42.8	43.0	43.1	43.2	43.3	43.4	43.5	43.6	43.7	43.8	43.4	43.0	42.6	42.4	42.1
SD	.57	.58	.56	.52	.51	.51	.48	.47	.47	.48	.53	.53	.55	.61	.61	.58	.54	.67	.77

*Exposure period begins at minute three and ends at minute thirteen.

TABLE A4.4-5

CLOACAL TEMPERATURES (^{o}C) OF FIVE HOUSE FINCHES IRRADIATED* PARALLEL TO THE E VECTOR OF A 50 mW/cm^{2} MICROWAVE FIELD FOR TEN MINUTES

MINUTES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIRD																			
Y35	42.7	42.7	42.8	42.8	43.3	43.8	44.3	44.7	45.1	45.6	46.1	46.6	46.7	47.8	--	--	--	--	--
Y37	41.6	41.7	41.7	41.8	42.3	42.6	43.0	43.3	43.7	44.1	44.5	44.7	44.9	45.2	45.0	44.5	44.0	43.4	42.9
W53	43.7	43.7	43.6	43.6	44.2	44.8	45.3	45.5	46.0	46.4	46.7	47.0	47.3	47.8	--	--	--	--	--
B1	42.9	42.9	42.9	42.9	43.5	44.0	44.6	45.1	45.7	46.3	46.8	47.4	47.9	48.5	--	--	--	--	--
O11	42.0	41.9	42.0	42.0	42.7	43.3	43.8	44.4	44.7	44.8	45.0	45.1	45.3	45.3	44.6	43.9	43.1	42.4	41.7
$\bar{X}$	42.6	42.6	42.6	42.6	43.2	43.7	44.2	44.6	45.0	45.4	45.8	46.1	46.5	46.9	44.8	44.2	43.5	42.9	42.3
SD	.82	.78	.75	.73	.73	.82	.86	.94	.91	.98	1.0	1.2	1.3	1.6	.28	.42	.64	.71	.85

*Exposure period begins at minute three and ends at minute thirteen.

--Bird died (Y 35 and W 53), or probe dislodged before the end of observation period; no temperatures recorded.

TABLE A4.4-6

RESULTS OF REGRESSION ANALYSIS OF TEMPERATURE PROFILES FOR IRRADIATED HOUSE FINCHES

Treatment	Minutes	Intercept	Δ Degrees Per Min.	F	df	p
SHAM	0 - 3	42.41	+.05	.48	1.34	>.05
	3 - 13	42.62	-.03	2.77	1.97	>.05
	13 - 18	42.69	-.03	.42	1.52	>.05
25 mW/cm^2 perpendicular	0 - 3	41.47	+.00	0.00	1.38	>.05
	3 - 5	40.92	+.19	1.86	1.28	>.05
	5 - 13	42.26	-.07	5.69	1.88	<.05
	13 - 18	43.11	-.15	1.43	1.58	>.05
25 mW/cm^2 parallel	0 - 3	42.26	-.06	8.85	1.38	<.01
	3 - 6	41.64	+.16	14.24	1.38	<.05
	6 - 13	42.89	-.04	4.76	1.78	<.05
	13 - 18	45.59	-.26	42.77	1.58	<.001
50mW/cm^2 perpendicular	0 - 3	42.26	+.03	.17	1.38	>.05
	3 - 13	42.11	+.12	67.44	1.108	<.001
	13 - 18	48.59	-.35	54.66	1.58	<.001
50 mW/cm^2 parallel	0 - 3	42.55	+.04	0.09	1.18	>.05
	3 - 13	41.63	+.41	107.77	1.53	<.001
	13 - 18	53.17	-.60	66.32	1.10	<.001

TABLE A4.4-7

CLOACAL TEMPERATURES (^{o}C) OF TEN SHAM IRRADIATED ($0\ mW/cm^{2}$) BLUE JAYS MONITORED FOR EIGHTEEN MINUTES

MINUTES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIRD																			
W-DB	44.2	44.1	44.0	43.9	43.9	43.8	43.7	43.6	43.5	43.5	43.5	43.5	43.5	43.4	43.3	43.2	43.1	43.1	43.1
-W	43.4	43.3	43.3	43.3	43.2	43.2	43.2	43.1	43.0	43.0	43.0	43.0	43.0	43.1	43.1	43.1	43.2	43.2	43.2
-DB	44.4	44.3	44.2	44.2	44.1	44.1	44.0	44.0	44.0	44.0	44.2	44.1	44.2	44.1	44.1	43.9	43.8	43.9	44.1
-R	43.6	43.5	43.5	43.5	43.5	43.4	43.4	43.4	43.4	43.4	43.5	43.5	43.5	43.5	43.4	43.4	43.4	43.3	43.2
LB-	43.9	43.8	43.8	43.8	43.7	43.6	43.5	43.5	43.5	43.5	43.5	43.4	43.4	43.3	43.3	43.3	43.3	43.3	43.3
DB-	43.6	43.4	43.3	43.2	43.1	43.1	43.0	43.0	42.9	43.0	42.9	42.8	42.8	42.8	42.7	42.6	42.6	42.8	42.8
LB-W	43.4	43.2	43.1	43.0	42.9	42.8	42.7	42.7	42.7	42.6	42.6	42.6	42.7	42.7	42.7	42.9	43.1	42.9	42.9
G-R	43.4	43.3	43.3	43.3	43.2	43.2	43.2	43.2	43.1	43.2	43.3	43.4	43.4	43.3	43.2	43.2	43.1	43.1	43.0
R-	43.4	43.2	43.1	43.0	42.9	42.8	42.8	42.8	42.7	42.7	42.6	42.5	42.5	42.4	42.3	42.3	42.3	42.2	42.2
-G	43.9	43.8	43.8	43.7	43.7	43.6	43.5	43.4	43.4	43.4	43.5	43.4	43.4	43.4	43.4	43.3	43.1	43.1	43.1
$\overline{X}$	43.7	43.6	43.5	43.5	43.4	43.4	43.3	43.3	43.2	43.2	43.3	43.2	43.2	43.2	43.1	43.1	43.1	43.1	43.1
SD	.36	.39	.39	.40	.42	.42	.40	.39	.41	.42	.49	.49	.50	.48	.49	.44	.41	.43	.47

TABLE A4.4-8

CLOACAL TEMPERATURES (°C) OF TEN BLUE JAYS IRRADIATED[a] WITH 10 mW/cm^2 ORIENTED PERPENDICULAR TO THE E VECTOR OF THE MICROWAVE FIELD FOR TEN MINUTES

MINUTE BIRD	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
-LB	42.8	42.7	42.7	42.6	42.6	42.6	42.6	42.6	42.6	42.5	42.5	42.5	42.5	42.5	42.4	42.3	42.3	42.3	42.3
G-R	42.8	42.8	42.8	42.7	42.7	42.9	42.8	42.7	42.6	42.5	42.4	42.4	42.4	42.4	42.2	42.1	42.1	42.3	42.4
DB-	43.1	43.0	42.9	42.9	42.9	42.7	42.7	42.6	42.6	42.6	42.5	42.5	42.5	42.5	42.5	42.5	42.4	42.3	42.2
LB-W	42.8	42.7	42.6	42.6	42.4	42.4	42.4	42.6	42.8	43.0	43.1	43.0	43.0	43.0	42.8	42.6	42.4	42.3	42.2
-W	43.3	43.2	43.2	43.1	43.2	43.3	43.2	43.2	43.1	43.0	43.1	43.1	43.1	43.0	43.0	43.1	43.1	43.1	43.1
-G	42.3	42.3	42.2	42.1	42.2	42.2	42.2	42.2	42.2	42.2	42.3	42.3	42.4	42.3	42.2	42.1	42.1	42.0	42.0
-DB	42.3	42.2	42.2	42.1	42.1	42.2	42.3	42.3	42.2	42.2	42.1	42.1	42.1	42.1	42.0	41.9	41.9	41.8	41.8
-R	43.2	43.1	43.0	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.8	42.8	42.7	42.7	42.6	42.5	42.4	42.4	42.3
R-	42.3	42.2	42.1	42.0	42.0	42.0	41.9	41.9	41.8	41.8	41.8	41.8	41.8	41.7	41.6	41.5	41.5	41.5	41.5
-LB	42.5	42.4	42.3	42.2	42.3	42.3	42.3	42.6	42.5	42.8	42.8	42.7	42.5	42.4	42.1	41.9	41.8	41.7	41.7
$\bar{X}$	42.7	42.7	42.6	42.5	42.5	42.6	42.5	42.6	42.5	42.5	42.5	42.5	42.5	42.5	42.3	42.2	42.2	42.2	42.1
SD	.38	.35	.38	.39	.38	.42	.38	.37	.38	.40	.42	.40	.38	.39	.41	.45	.43	.45	.45

[a] Exposure Period begins at minute three, and ends at minute thirteen.

TABLE A4.4-9

CLOACAL TEMPERATURES (°C) OF TEN BLUE JAYS IRRADIATED* WITH 25 mW/cm^2

ORIENTED PERPENDICULAR TO THE E VECTOR OF THE MICROWAVE FIELD FOR TEN MINUTES

MINUTES BIRD	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
-LB	42.7	42.7	42.7	42.7	42.8	43.0	43.0	43.0	42.9	42.9	42.9	43.0	43.0	43.0	42.8	42.7	42.5	42.4	42.3
G-R	42.5	42.5	42.5	42.4	42.6	42.7	42.8	42.7	42.7	42.6	42.5	42.4	42.4	42.5	42.3	42.2	42.1	41.9	41.8
DB-	43.1	43.0	42.9	42.9	43.0	43.0	42.9	42.9	42.9	42.8	42.8	42.7	42.8	42.7	42.6	42.6	42.7	42.7	42.6
LB-W	43.2	43.0	42.9	42.8	43.0	43.1	43.0	43.0	43.1	43.1	43.1	43.2	43.2	43.2	43.2	43.1	43.0	43.0	42.9
-W	42.4	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.2	42.2	42.2	42.2	42.2	42.2	42.1	42.0	41.8	41.7	41.7
-G	43.4	43.2	43.1	43.1	43.2	43.3	43.5	43.5	43.5	43.4	43.4	43.5	43.5	43.5	43.3	43.1	42.8	42.8	42.8
W-DB	43.9	43.8	43.7	43.6	43.7	43.8	43.8	43.8	43.8	43.7	43.7	43.6	43.6	43.6	43.4	43.4	43.3	43.3	43.0
-DB	43.4	43.4	43.4	43.4	43.7	43.8	43.9	43.9	43.8	44.0	44.3	44.5	44.5	44.7	44.5	44.2	43.9	43.6	43.4
-R	43.0	43.0	42.9	42.8	43.0	43.2	43.3	43.3	43.4	43.4	43.4	43.4	43.4	43.5	43.4	43.2	43.0	42.9	42.8
R-	42.4	42.3	42.2	42.2	42.3	42.4	42.5	42.5	42.5	42.5	42.5	42.5	42.3	42.4	42.1	42.0	42.0	41.9	41.9
$\overline{X}$	43.0	42.9	42.9	42.8	42.9	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.1	43.0	42.8	42.7	42.6	42.5
SD	.50	.48	.47	.46	.49	.51	.52	.53	.54	.57	.64	.69	.71	.74	.75	.69	.64	.63	.57

*Exposure period begins at minute three, and ends at minute thirteen.

TABLE A4.4-10

CLOACAL TEMPERATURES (°C) OF TEN BLUE JAYS IRRADIATED[a] PARALLEL
TO THE E VECTOR OF A 25 mW/cm^{2}H MICROWAVE FIELD

MINUTE	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BIRD																			
LB-	42.9	42.8	42.8	42.8	43.0	43.0	43.0	43.1	43.2	43.1	43.2	43.2	43.2	43.3	42.9	42.7	42.6	42.5	42.3
G-R	43.2	43.1	43.0	43.0	43.3	43.5	43.7	43.6	43.7	43.8	43.9	43.9	44.1	44.1	43.8	43.5	43.3	43.0	42.9
DD-	43.4	43.3	43.3	43.3	43.8	43.9	44.2	44.3	44.3	44.7	44.5	44.5	43.9	43.1	42.5	--	--	--	--
LB-W	43.1	42.9	42.9	42.9	43.1	43.3	43.4	43.6	43.7	43.8	43.9	44.0	44.3	44.4	44.2	43.9	43.8	43.6	43.5
-W	43.2	43.1	43.1	43.0	43.5	43.7	43.7	43.6	43.7	43.8	43.8	43.9	43.9	44.1	43.6	43.4	43.2	43.0	42.9
-G	43.4	43.3	43.2	43.2	43.5	43.6	43.7	43.8	43.9	43.9	43.9	43.9	44.0	44.0	43.7	43.5	43.3	43.1	43.0
W-DB	43.1	43.0	42.9	42.8	42.9	43.0	43.1	43.1	43.2	43.3	43.3	43.4	43.4	43.5	43.4	43.2	43.0	42.8	42.7
-DB	43.3	43.2	43.2	43.2	43.4	43.6	43.7	43.8	43.8	43.9	44.5	44.8	45.0	45.3	44.8	44.4	44.2	43.9	43.7
-R	43.5	43.4	43.3	43.3	43.6	43.6	43.8	43.8	43.9	43.9	44.0	44.0	44.0	44.1	43.9	43.7	43.5	43.3	43.2
R-	43.0	42.9	42.8	42.7	42.8	42.9	43.0	43.1	43.2	43.2	43.3	43.4	43.4	43.4	43.1	42.9	42.7	42.6	42.5
$\bar{X}$	43.2	43.1	43.0	43.0	43.3	43.4	43.5	43.6	43.7	43.7	43.8	43.9	43.9	43.9	43.6	43.5	43.3	43.1	43.0
SD	.82	.78	.78	.76	.87	.80	.70	.83	.78	.81	.65	.94	.65	.79	.79	.70	.69	.78	.74

[a] Exposure period begins at minute three, and ends at minute thirteen.

--Probe dislodged from cloaca before the end of observation period; no temperatures recorded.

TABLE A4.4-11

CLOACAL TEMPERATURES (°C) OF TEN BLUE JAYS IRRADIATED* WITH 50 mW/cm^2 ORIENTED PERPENDICULAR TO THE E VECTOR OF THE MICROWAVE FIELD FOR TEN MINUTES

MINUTES BIRD	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LB-	42.8	42.8	42.7	42.8	42.9	43.0	43.0	43.1	43.3	43.4	43.5	43.6	43.7	43.8	43.6	43.4	43.3	43.1	43.0
G-R	42.7	42.7	42.6	42.5	42.8	42.7	42.8	42.9	43.1	43.3	43.8	44.1	44.3	44.8	44.4	44.3	44.3	43.9	44.2
DB-	43.1	43.1	43.0	43.0	43.3	43.6	43.9	44.1	44.4	44.5	44.6	44.4	44.5	44.6	--	--	--	--	--
LB-W	42.8	42.7	42.7	42.8	43.2	43.4	43.5	43.7	43.8	44.0	44.2	44.3	44.3	44.6	44.2	44.0	43.7	43.5	43.3
-W	43.3	43.2	43.1	43.1	43.4	43.6	43.7	43.4	43.5	43.8	43.9	44.2	44.5	44.5	44.7	44.8	44.4	--	--
-G	43.4	43.4	43.3	43.3	43.6	43.8	43.9	44.0	44.1	44.1	44.2	44.3	44.4	44.5	44.3	44.1	44.0	43.8	43.7
W-DB	43.1	43.0	43.0	42.9	43.3	43.5	43.6	43.7	43.7	43.8	43.9	44.0	44.1	44.1	43.8	43.5	43.1	42.7	42.5
-DB	43.9	43.8	43.7	43.8	44.1	44.3	43.8	44.4	44.6	44.7	44.8	45.0	45.2	45.5	45.3	45.1	44.8	44.6	44.4
-R	43.4	43.3	43.2	43.2	43.4	43.5	43.6	43.7	43.9	43.9	44.0	44.2	44.3	44.4	44.3	44.0	43.8	43.6	43.5
R-	42.1	42.0	42.0	42.0	42.3	42.3	42.3	42.4	42.6	42.7	42.9	43.0	43.2	43.3	43.1	43.0	42.9	42.8	42.6
$\overline{X}$	43.1	43.0	42.9	42.9	43.2	43.4	43.4	43.5	43.7	43.8	44.0	44.1	44.2	44.4	44.2	44.0	43.8	43.5	43.4
SD	.49	.49	.46	.48	.49	.57	.53	.60	.60	.58	.54	.52	.53	.59	.64	.67	.63	.63	.69

*Exposure period begins at minute three, and ends at minute thirteen.

--Probe dislodged from cloaca before the end of observation period; no temperatures recorded.

TABLE A4.4-12

RESULTS OF REGRESSION ANALYSIS OF TEMPERATURE PROFILES FOR IRRADIATED BLUE JAYS

Treatment	Minutes	Intercept	Δ Degrees Per Min.	F	df	p
SHAM	0 - 3	43.69	-.07	1.93	1.38	>0.05
	3 - 13	43.49	-.02	3.71	1.108	>0.05
	13 - 18	43.13	-.00	0.00	1.58	>0.05
10 mW/cm^2 perpendicular	0 - 3	42.74	-.07	1.87	1.38	>0.05
	3 - 13	42.56	-.01	0.23	1.108	>0.05
	13 - 18	43.20	-.06	3.66	1.58	>0.05
25 mW/cm^2 perpendicular	0 - 3	42.99	-.06	0.34	1.38	>0.05
	3 - 5	42.47	+.12	1.26	1.28	>0.05
	5 - 13	43.05	0.00	0.03	1.88	>0.05
	13 - 18	44.68	-.12	6.06	1.58	<0.05
25 mW/cm^2 parallel	0 - 3	43.19	-.06	4.91	1.38	<0.05
	3 - 13	42.94	+.08	44.35	1.108	<0.001
	13 - 18	44.66	-.21	27.27	1.52	<0.001
50 mW/cm^2 perpendicular	0 - 3	43.07	-.04	0.42	1.38	>0.05
	3 - 13	42.61	+.14	73.90	1.108	<0.001
	13 - 18	46.92	-.20	14.14	1.46	<0.001

APPENDIX A4.5-1

Flight Feather Scores vs. Date

(abbreviations: PP = primaries, SS = secondaries, TT = tertials, TL = tail)

(a) Exposure: 10 mW/cm^2

	Bird # W2 (10 mW/cm^2)					Bird # G8 (10 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
30 Jun	-	-	-	-	-	0	0	0	0	0
08 Jul	0	0	0	0	0	0	0	0	0	0
16 Jul	0	0	0	0	0	0	0	0	0	0
23 Jul	3	0	0	0	3	0	0	0	0	0
30 Jul	11	0	0	0	11	0	0	0	0	0
06 Aug	16	0	0	0	16	0	0	0	0	0
19 Aug	26	0	2	0	28	1	0	0	0	1
28 Aug	32	0	6	0	38	8	0	0	0	8
04 Sep	38	0	11	4	53	9	0	0	0	9
09 Sep	42	0	15	9	66			Died		
19 Sep	50	1	19	24	94					
25 Sep	54	4	23	31	112					
02 Oct	60	7	27	37	131					
15 Oct	73	14	30	52	169					
21 Oct	78	19	30	54	181					
31 Oct	82	21	30	58	191					
07 Nov	85	32	30	60	207					
14 Nov	88	38	30	60	216					
25 Nov	89	42	30	60	221					
05 Dec	90	48	30	60	228					

APPENDIX A4.5-1 (continued)

	Bird # G9 (10 mW/cm^2)					Bird # G15 (10 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
16 Jul	0	0	0	0	0	0	0	0	0	0
23 Jul	0	0	0	0	0	0	0	0	0	0
30 Jul	0	0	0	0	0	0	0	0	0	0
06 Aug	0	0	0	0	0	1	0	0	0	1
19 Aug	7	0	0	0	7	11	0	0	0	11
28 Aug	20	0	2	2	24	22	0	2	0	24
04 Sep	29	0	3	4	36	29	0	5	1	35
09 Sep	35	0	4	6	45	32	0	7	5	44
19 Sep	47	0	7	14	68	43	0	10	10	63
25 Sep	52	1	9	20	82	48	0	11	12	71
02 Oct	58	2	13	27	100	52	3	15	18	88
15 Oct	66	8	19	41	134	60	8	23	29	120
21 Oct	70	10	21	47	148	64	9	25	39	137
31 Oct	80	18	28	54	180	76	14	29	50	169
07 Nov	84	26	30	56	196	80	19	30	54	183
14 Nov	88	38	30	57	213	87	28	30	56	201
25 Nov	90	49	30	59	228	88	43	30	59	220
05 Dec	90	54	30	60	234	90	55	30	60	235

APPENDIX A4.5-1 (continued)

(d) Exposure: 25 mW/cm^2

	Bird # W41 (25 mW/cm^2)					Bird # W42 (25 mW/cm^2)				
Date	**PP**	**SS**	**TT**	**TL**	**TOTAL**	**PP**	**SS**	**TT**	**TL**	**TOTAL**
04 Sep	45	4	14	16	79	62	13	24	37	126
09 Sep	52	6	18	17	93	64	18	27	40	149
19 Sep	57	8	25	29	119	68	23	29	51	171
25 Sep	58	10	25	33	126	71	25	30	55	181
02 Oct	59	10	25	42	136	73	25	30	55	183
15 Oct	66	12	27	51	156	82	25	30	55	192
21 Oct	68	15	28	54	165	84	25	30	55	194
31 Oct	76	21	30	59	186	88	29	30	57	204
07 Nov	80	27	30	60	197	90	30	30	58	208
14 Nov	84	31	30	60	205	90	31	30	59	210
25 Nov	88	37	30	60	215	90	34	30	60	214
05 Dec	90	40	30	60	220	90	35	30	60	215

APPENDIX A4.5-1 (continued)

	Bird # G13 (0 mW/cm^2)					Bird # W59 (0 mW/cm^2)				
Date	**PP**	**SS**	**TT**	**TL**	**TOTAL**	**PP**	**SS**	**TT**	**TL**	**TOTAL**
16 Jul	4	0	0	0	4					
23 Jul	9	0	0	0	9					
30 Jul	16	0	0	0	16					
06 Aug	17	0	0	0	17					
19 Aug	26	0	4	0	30	Late Addition				
28 Aug	38	1	7	5	51	62	11	25	33	131
04 Sep	[illegible]	4	14	10	76	64	18	26	49	157
09 Sep	[illegible]4	6	18	13	91	68	21	29	51	169
19 Sep	63	13	25	26	127	70	24	30	55	179
25 Sep	68	20	29	39	156	72	25	30	57	184
02 Oct	76	27	30	46	179	75	27	30	58	190
15 Oct	87	41	30	58	216	81	33	30	59	203
21 Oct	88	47	30	59	224	82	34	30	60	206
31 Oct	90	58	30	60	238	86	35	30	60	211
07 Nov	90	60	30	60	240	88	39	30	60	217
14 Nov	Complete					88	43	30	60	221
25 Nov						90	52	30	60	232
05 Dec						90	55	30	60	235

APPENDIX A4.5-1 (continued)

Bird # W60 (0 mW/cm^2)

Date	PP	SS	TT	TL	TOTAL
		Late Addition			
28 Aug	65	23	30	50	168
04 Sep	70	28	30	58	186
09 Sep	74	28	30	58	190
19 Sep	82	30	30	60	202
25 Sep	84	30	30	60	204
02 Oct	84	31	30	60	205
15 Oct	88	37	30	60	215
21 Oct	88	38	30	60	216
31 Oct	90	46	30	60	226
07 Nov	90	53	30	60	233
14 Nov	90	58	30	60	238
25 Nov	90	60	30	60	240
		Complete			

APPENDIX A4.5-1 (continued)

	Bird # G5 (0 mW/cm^2)					Bird # G6 (0 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
30 Jun	0	0	0	0	0	0	0	0	0	0
08 Jul	4	0	0	0	4	2	0	0	0	2
16 Jul	12	0	0	0	12	10	0	0	0	10
23 Jul	21	0	0	0	21	18	0	0	0	18
30 Jul	28	0	0	0	28	22	0	0	0	22
06 Aug	31	0	0	0	31	29	0	3	0	32
19 Aug	43	0	5	2	50	46	1	9	10	66
28 Aug	52	4	13	16	85	55	6	19	26	106
04 Sep	60	10	18	27	115	65	12	24	43	144
09 Sep	62	12	20	37	131	71	19	28	54	172
19 Sep	74	23	25	50	172	82	29	30	51	192
25 Sep	84	30	28	56	198	86	35	30	51	202
02 Oct	86	39	28	59	212	88	42	30	54	214
15 Oct	90	54	30	60	234	90	55	30	58	233
21 Oct	90	58	30	60	238	90	59	30	60	239
31 Oct	90	60	30	60	240	90	60	30	60	240
	Complete					Complete				

APPENDIX A4.5-1 (continued)

(b) Exposure: 0 mW/cm^2 (controls)

	Bird # G2 (0 mW/cm^2)					Bird # G3 (0 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
30 Jun	15	0	0	5	20	-	-	-	-	-
08 Jul	24	0	0	6	30	4	0	0	0	4
16 Jul	28	0	0	10	38	13	0	0	0	13
23 Jul	32	0	2	12	46	16	0	0	0	16
30 Jul	33	0	6	15	54	21	0	1	0	22
06 Aug	35	0	9	18	62	24	0	3	0	27
19 Aug	42	1	13	20	76	35	0	9	2	46
28 Aug	50	3	18	24	95	46	0	15	12	73
04 Sep	57	8	23	27	115	55	3	21	28	107
09 Sep	60	13	26	33	132	60	5	25	34	124
19 Sep	69	18	29	42	158	73	10	29	47	159
25 Sep	72	24	30	48	174	78	15	29	55	177
02 Oct	82	30	30	56	198	84	21	30	58	193
15 Oct	88	45	30	59	222	88	37	30	60	215
21 Oct	88	54	30	59	231	90	45	30	60	225
31 Oct	90	59	30	60	239	90	55	30	60	235
07 Nov	90	60	30	60	240	90	58	30	60	238
14 Nov		complete				90	60	30	60	240
							complete			

APPENDIX A4.5-1 (continued)

(c) Exposure: 1 mW/cm^2

	Bird # G22 (1 mW/cm^2)					Bird # W56 (1 mW/cm^2)				
Date	**PP**	**SS**	**TT**	**TL**	**TOTAL**	**PP**	**SS**	**TT**	**TL**	**TOTAL**
23 Jul	4	0	0	0	4	26	0	5	1	32
30 Jul	10	0	0	0	10	35	0	8	2	45
06 Aug	14	0	0	0	14	38	0	9	3	50
19 Aug	26	1	0	0	27	48	0	10	4	62
28 Aug	36	2	4	2	44	52	0	12	11	75
04 Sep	44	6	11	6	67	55	2	13	13	83
09 Sep	49	9	15	11	84	58	4	16	16	94
19 Sep	58	15	22	25	120	64	8	23	25	120
25 Sep	66	19	28	39	152	68	10	27	34	139
02 Oct	73	25	28	46	172	70	13	28	42	153
15 Oct	84	36	30	56	206	82	18	30	50	180
21 Oct	86	43	30	58	217	84	23	30	57	194
31 Oct	88	51	30	58	227	88	31	30	60	209
07 Nov	90	59	30	60	239	90	38	30	60	218
14 Nov	90	60	30	60	240	90	42	30	60	222
25 Nov		complete				90	50	30	60	230
05 Dec						90	58	30	60	238

APPENDIX A4.5-1 (continued)

	Bird # W43 (10 mW/cm^2)					Bird # W44 (10 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
16 Jul	0	0	0	0	0	0	0	0	2	2
23 Jul	0	0	0	0	0	1	0	0	4	5
30 Jul	0	0	0	0	0	3	0	0	5	8
06 Aug	1	0	0	0	1	7	0	0	7	14
19 Aug	12	0	0	0	12	21	0	4	13	38
28 Aug	19	0	0	0	19	28	0	10	15	53
04 Sep	24	0	2	0	26	35	0	13	16	64
09 Sep	36	0	4	0	40	41	0	13	18	72
19 Sep	41	1	9	6	57	50	0	20	26	96
25 Sep	44	3	12	9	68	53	0	20	32	105
02 Oct	50	5	18	16	89	56	0	20	39	115
15 Oct	60	12	27	31	130	66	5	26	46	143
21 Oct	62	16	28	48	154	70	7	28	51	156
31 Oct	73	25	30	50	178	80	14	30	56	180
07 Nov	79	29	30	55	193	84	19	30	59	192
14 Nov	84	35	30	58	207	88	26	30	59	203
25 Nov	88	45	30	60	223	90	39	30	60	219
05 Dec	90	51	30	60	231	90	55	30	60	235

APPENDIX A4.5-1 (continued)

	Bird # W57 (10 mW/cm^2)					Bird # W58 (10 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
30 Jun	0	0	0	0	0	0	0	0	0	0
08 Jul	0	0	0	0	0	0	0	0	0	0
16 Jul	0	0	0	0	0	0	0	0	1	1
23 Jul	0	0	0	0	0	0	0	0	1	1
30 Jul	2	0	0	0	2	6	0	0	2	8
06 Aug	5	0	0	0	5	12	0	0	3	15
19 Aug	20	0	3	0	23	26	0	2	5	33
28 Aug	26	0	7	0	33	36	0	8	6	50
04 Sep	31	0	9	0	40	44	0	15	9	68
09 Sep	36	0	11	0	47	49	1	18	15	83
19 Sep	43	4	15	8	70	56	6	23	22	107
25 Sep	46	6	18	13	83	62	10	26	30	128
02 Oct	52	10	22	23	107	66	18	28	40	152
15 Oct	62	18	28	41	149	80	31	30	55	196
21 Oct	67	24	28	50	169	84	39	30	57	210
31 Oct	78	31	30	56	195	88	48	30	60	226
07 Nov	84	44	30	60	218	90	56	30	60	236
14 Nov	87	54	30	60	231	90	58	30	60	238
25 Nov	90	59	30	60	239	90	60	30	60	240
05 Dec	90	60	30	60	240			complete		
		complete								

APPENDIX A4.5-1 (continued)

	Bird # G17 (10 mW/cm^2)					Bird # (10 mW/cm^2)				
Date	PP	SS	TT	TL	TOTAL	PP	SS	TT	TL	TOTAL
30 Jun	-	-	-	-	-	0	0	0	0	0
08 Jul	-	-	-	-	-	0	0	0	0	0
16 Jul	0	0	0	2	2	0	0	0	0	0
23 Jul	1	0	0	3	4	0	0	0	0	0
30 Jul	2	0	0	4	6	0	0	0	0	0
06 Aug	6	0	0	4	10	2	0	0	0	2
19 Aug	16	0	0	5	21	16	0	0	0	16
28 Aug	27	0	4	6	37	29	0	4	1	34
04 Sep	33	0	7	7	47	36	0	9	6	51
09 Sep	38	0	9	9	56	43	2	12	10	67
19 Sep	46	2	16	13	77	53	6	21	28	108
25 Sep	50	4	18	17	89	59	9	26	34	128
02 Oct	54	7	20	25	106	66	13	29	42	150
15 Oct	64	13	26	32	135	79	26	30	56	191
21 Oct	70	17	28	38	153	86	35	30	58	209
31 Oct	79	27	30	47	183	88	49	30	59	226
07 Nov	84	34	30	56	204	90	56	30	60	236
14 Nov	88	40	30	57	215	90	60	30	60	240
25 Nov	90	47	30	60	227			complete		
05 Dec	90	53	30	60	233					

APPENDIX A4.5-2

NECROPSY HISTOPATHOLOGY

The
University
of
Connecticut

STORRS, CONNECTICUT 06268
COLLEGE OF AGRICULTURE
AND NATURAL RESOURCES
Th. Northeastern Research Center for Wildlife Diseases

June 10, 1981

Dr. Samuel Battista
Arthur D. Little, Inc.
Acorn Park
Cambridge, MA 02140

Dear Dr. Battista:

The necropsy, hematologic and histopathologic findings of 12 House Finches (Lapordacus mexicanus) is attached, as is the itemized cost. All formalin fixed tissues, paraffin blocks and 12 boxes with 3 epon embedded sections of the eye, are mailed under separate cover. The 12 birds examined were 6 exposed to high dose of microwave and 6 control birds. Six low dose birds were kept for observation and possible necropsy if the high dose birds had lesions or hematologic changes. Since no treatment related lesions were found in the high level birds, the 6 birds were released in a perfectly healthy state 4 weeks later, as per your instructions.

I trust the enclosed meet with your approval. If you have any questions please do not hesitate in calling me 203-486-4000.

Yours truly,

Svend W. Nielsen, D.V.M., Ph.D.
Director & Professor of Pathobiology

SWN/jc
Enclosure

Methods

On April 28, 1981 the 12 birds (6 high dose and 6 controls) were individually placed in a container above a block of dry ice. Carbon dioxide narcosis developed in 2-3 minutes, the bird was taken out and examined and a necropsy performed immediately. Two milliliters of blood was used for hematocrit, hemoglobin, total nucleated cell count, and differential count determinations. A necropsy was performed with special emphasis on gross inspection of lens, cornea, bone marrow, genitalia and internal viscera. One entire eye was fixed in chilled glutaraldehyde and the following tissues in 10% formalin: eye, brain, longitudinally split femur, and slices of liver, kidney with adrenal, transversal section of ovary/testis with spinal cord and vertebral marrow, and ventral neck with thyroid and thymus. The formalin fixed tissues were embedded in paraffin, cut at 6 microns and stained with hematoxylin-eosin. Due to a technician's error the tissues from 1 control (bird 6) were not processed and tissues from 4 high dose birds (7, 8, 11, and 12) were combined and processed under the number of 81:2077. The bone marrows are labelled A,B,C, and D respectively.

Results

1. Hematologic Findings: There was no significant difference between the control and treated birds in means of: Total Cell Count: 1.95 vs. 1.93 million per cmm^3; hematocrit: 42.8 vs. 41.5 per cent and hemoglobin: 15.0 vs. 14.0 grms per 100 ml. The differential counts had a mean of 75% lymphocytoid cells, with one bird (#10) with 95%, but its total cell count was not elevated (1.83 mill./cm^3).

Hematologic Findings continued

Bird No.	Leg Band	Blood Cells	Hematocrit	Hemoglobin
1	black-yellow	1.98	46	15.5
2	pink-pink green	1.82	37	13
3	orange-white	2.16	46	16
4	black-0	1.56	37	14.5
5	black-white	2.24	49	16
6	black-red	1.99	42	15
7	0-white 42	2.61	50	16.5
8	blue-white	1.98	44	15
9	0-green pink	1.64	34	11.5
10	0-white	1.83	41	13.5
11	CS-black	1.48	35	13
12	0-white	2.06	45	15

AVERAGE OF CONTROL (Birds 1-6)

Total Cell Count	11.75 ÷ 6 = 1.95
Hematocrit	257 ÷ 6 = 42.8
Hemoglobin	90 ÷ 6 = 15.0

AVERAGE OF HIGH DOSE (Birds 7-12)

Total Cell Count	11.6 ÷ 6 = 1.93
Hematocrit	249 ÷ 6 = 41.5
Hemoglobin	84.5 ÷ 6 = 14.0

Results: 2. Gross Pathologic Findings

No differences were observed in the size, shape and color of skin, cornea, lens, brain and internal viscera between the control group (1-6) and the high level group (7-12). The amount of body fat, feathering, intestinal contents and breast muscle mass were the same in the 2 groups. The ovary of the only female in the high dose group had several maturing follicles as did birds in the control group indicating that the birds were approaching the egg production stage. No parasites were found in any of the birds.

3. Histopathologic Findings

The only microscopic lesions were two focal granulomas in the kidney of a treated bird, which were incidental findings, compatible with larvae migrans lesions. The eye, lens, brain, spinal cord, bone marrow of both femur and spinal vertebra, liver, kidney, thymus, ovary, testis and endocrine organs were of the same appearance morphologically in both groups. A further search for possible changes in the remaining fixed tissues or the paraffin blocks will require additional work. Three epon embedded sections of one lens from each of the 12 birds may also be cut and examined under the electron microscope, however these expenses do not appear justified based on the absence of lesions under the light microscope.

IDENTIFICATION

Bird No.	CONTROL		
1	B-Y	Female	(81:2071)
2	P-PG	Male	(81:2072)
3	O-W	Female	(81:2073)
4	Black--	Female	(81:2074)
5	Black-W	Male	(81:2075)
6	Black-R	Female	(81:2076)
	HIGH DOSE		
7	Ø-W 42	Male	(81:2077)
8	B-W	Male	(81:2078)
9	Ø-GP	Female	(81:2079)
10	Ø-W 59	Male	(81:2080)
11	CS-BL	Male	(81:2081)
12	Ø-W	Male	(81:2082)

Leg band and color - read left side first

Symbols:
- B=Blue
- P=Pink
- Y=Yellow
- GP=Green Pink
- O=Orange
- W=White
- CS=Candystripe red/white
- Ø=No Band
- R=Red

TABLE A4.6-1

MEAN ± STANDARD DEVIATIONS FOR NUMBER OF PREY EATEN FOR MULTIPLE ACUTE EXPOSURES AT 0.1, 10.0 AND 25.0 mW/cm^2

Bird No.	PD	Time Expo.	a	$\overline{X}$	± SD	b	$\overline{X}$	± SD	c	$\overline{X}$	± SD	d	$\overline{X}$	± SD
1	0.1	2	S	1.7	± 1.2	S	4.7	± 2.3	S	5.7	± 2.9	S	3.3	± 1.5
2	0.1	2	S	4.0	0.0	E	6.7	2.9	S	5.3	1.2	E	3.3	0.6
3	0.1	20	S	5.3	1.5	S	4.0	0.0	S	5.7	0.6	S	3.3	0.6
4	0.1	20	S	4.7	2.3	E	7.0	2.6	S	6.3	2.1	E	2.7	1.2
5	0.1	200	S	6.0	1.0	S	6.7	1.2	S	9.0	2.6	S	4.3	0.6
6	0.1	200	S	6.7	2.1	E	8.7	2.1	S	6.3	0.6	E	5.3	2.5
1	10.0	2	S	9.7	± 0.6	S	7.0	± 2.6	S	4.7	± 2.0	S	4.0	± 2.6
2	10.0	2	S	9.3	1.2	E	8.0	1.7	S	6.0	1.0	E	5.0	0.0
3	10.0	20	S	7.7	3.5	S	6.3	1.2	S	2.3	0.6	S	4.3	1.5
4	10.0	20	S	5.7	0.6	E	5.7	1.2	S	5.7	1.2	E	7.7	2.1
5	10.0	200	S	7.7	2.1	S	11.0	1.0	S	7.0	1.0	S	8.3	2.1
6	10.0	200	S	12.3	1.2	E	9.0	3.0	S	7.8	0.6	E	8.3	1.5
1	25.0	2	S	6.3	± 1.2	S	3.3	± 1.2	S	7.7	± 1.5	S	5.7	± 1.5
2	25.0	2	S	4.7	1.2	E	4.7	1.5	S	4.7	1.2	E	3.0	1.0
3	25.0	20	S	3.0	1.0	S	5.7	0.6	S	7.3	0.6	S	5.0	1.7
4	25.0	20	S	6.7	0.6	E	7.0	1.7	S	5.7	1.2	F	5.7	3.8
5	25.0	200	S	7.3	2.5	S	8.0	0.0	S	6.7	0.6	S	7.3	3.2
6	25.0	200	S	7.7	1.5	E	6.7	1.2	S	7.7	2.3	F	4.3	1.5

PD = Power density in mW/cm^2
a = Week 1 with three observations per bird under sham conditions.
b = Week 2 with three observations per bird; birds 1, 2 and 3 under sham conditions and birds 2, 4 and 6 under irradiated condition.
c = Week 3 (see a)
d = Week 4 (see b)
$\overline{X}$ = mean of three observations per week
SD = standard deviation of mean

TABLE A4.6-2

MEAN AND STANDARD DEVIATIONS FOR SEARCH TIME IN SECONDS FOR MULTIPLE ACUTE EXPOSURES AT 0.1, 10.0 AND 25.0 mW/cm^2

Bird No.	PD	Time Expo.	a	$\bar{X}$	±	SD	b	$\bar{X}$	±	SD	c	$\bar{X}$	±	SD	d	$\bar{X}$	±	SD
1	0.1	2	S	156	±	73	S	171	±	49	S	173	±	72	S	168	±	11
2	0.1	2	S	138		37	E	218		115	S	165		89	E	264		144
3	0.1	20	S	116		82	S	169		68	S	136		32	S	170		66
4	0.1	20	S	74		40	E	143		36	S	132		76	E	142		72
5	0.1	200	S	149		14	S	163		38	S	132		52	S	245		138
6	0.1	200	S	151		48	E	209		74	S	235		78	E	233		135
1	10.0	2	S	99	±	13	S	169	±	92	S	84	±	46	S	82	±	57
2	10.0	2	S	103		21	E	104		44	S	92		52	E	84		21
3	10.0	20	S	205		192	S	139		62	S	125		101	S	57		36
4	10.0	20	S	105		28	E	122		16	S	80		42	E	79		14
5	10.0	200	S	90		30	S	136		30	S	74		23	S	91		35
6	10.0	200	S	172		17	E	189		96	S	163		96	F	160		39
1	25.0	2	S	75	±	22	S	39	±	8	S	125	±	19	S	65	±	17
2	25.0	2	S	75		5	E	96		81	S	53		16	F	56		17
3	25.0	20	S	31		13	S	65		26	S	79		22	S	76		23
4	25.0	20	S	76		24	E	61		13	S	63		34	E	47		13
5	25.0	200	S	71		32	S	74		29	S	70		17	S	89		74
6	25.0	200	S	59		8	E	95		43	S	107		32	E	46		20

PD = Power density in mW/cm^2
a = Week 1 with three observations per bird under sham conditions.
b = Week 2 with three observations per bird; birds 1, 3 and 5 under sham conditions and birds 2, 4 and 6 under irradiated condition.
c = Week 3 (see a)
d = Week 4 (see b)
$\bar{X}$ = mean of three observations per week
SD = standard deviation of mean

TABLE A4.6-3

MEAN AND STANDARD DEVIATIONS FOR HANDLING TIME IN SECONDS FOR MULTIPLE ACUTE EXPOSURES AT 0.1, 10.0 AND 25.0 mW/cm^2

Bird No.	PD	Time Expo.	a	$\bar{X}$	± SD	b	$\bar{X}$	± SD	c	$\bar{X}$	± SD	d	$\bar{X}$	± SD
1	0.1	2	S	15	± 15	S	93	± 102	S	35	± 21	S	31	± 11
2	0.1	2	S	31	10	E	66	12	S	38	9	E	18	6
3	0.1	20	S	34	22	S	17	3	S	19	2	S	13	3
4	0.1	20	S	29	18	E	40	21	S	22	9	E	7	2
5	0.1	200	S	43	16	S	61	8	S	44	16	S	43	7
6	0.1	200	S	35	9	E	42	7	S	21	5	E	19	9
1	10.0	2	S	49	± 10	S	32	± 8	S	23	± 14	S	20	± 14
2	10.0	2	S	43	20	E	33	8	S	35	7	E	25	8
3	10.0	20	S	27	14	S	19	1	S	7	3	S	14	8
4	10.0	20	S	21	6	E	15	2	S	13	3	E	29	10
5	10.0	200	S	37	12	S	52	14	S	43	17	S	58	14
6	10.0	200	S	45	5	E	33	6	S	22	0	E	30	7
1	25.0	2	S	48	± 11	S	25	± 16	S	54	± 16	S	37	± 12
2	25.0	2	S	28	4	E	29	3	S	28	4	E	24	11
3	25.0	20	S	11	5	S	26	9	S	29	2	S	27	9
4	25.0	20	S	33	5	E	38	7	S	28	4	E	33	23
5	25.0	200	S	74	41	S	119	31	S	40	5	S	89	74
6	25.0	200	S	46	18	E	48	7	S	53	17	E	42	4

PD = Power density in mW/cm^2
a = Week 1, three observations.
b = Week 2, three observations.
c = Week 3, three observations.
d = Week 4, three observations.
S = Sham treatment.
E = Exposure treatment.
$\bar{X}$ = Mean for the week.
SD = Standard deviation of the mean.

TABLE A4.6-4

MEAN ± STANDARD DEVIATION FOR PROFITABILITY (NO. OF PREY/SEARCH TIME + HANDLING TIME) FOR MULTIPLE ACUTE EXPOSURES AT 0.1, 10.0 AND 25.0 mW/cm^2

Bird No.	PD	Time Expo.	a	$\overline{X}$ ± SD		b	$\overline{X}$ ± SD		c	$\overline{X}$ ± SD		d	$\overline{X}$ ± SD	
1	0.1	2	S	.01 ±	.01	S	.02 ±	.01	S	.03 ±	.00	S	.02 ±	.01
2	0.1	2	S	.02	.01	E	.02	.01	S	.03	.02	E	.01	.01
3	0.1	20	S	.04	.01	S	.02	.01	S	.04	.01	S	.02	.00
4	0.1	20	S	.05	.01	E	.04	.00	S	.04	.01	E	.02	.01
5	0.1	200	S	.03	.00	S	.03	.00	S	.05	.01	S	.02	.01
6	0.1	200	S	.04	.01	E	.04	.00	S	.03	.01	E	.02	.01
1	10.0	2	S	.07 ±	.01	S	.04 ±	.00	S	.04 ±	.01	S	.04 ±	.01
2	10.0	2	S	.06	.01	E	.06	.01	S	.06	.01	E	.05	.01
3	10.0	20	S	.04	.02	S	.04	.01	S	.07	.02	S	.07	.02
4	10.0	20	S	.03	.02	E	.04	.01	S	.07	.05	E	.07	.01
5	10.0	200	S	.06	.01	S	.06	.02	S	.06	.01	S	.06	.00
6	10.0	200	S	.06	.00	E	.04	.02	S	.05	.02	E	.04	.00
1	25.0	2	S	.05 ±	.01	S	.05 ±	.02	S	.04 ±	.01	S	.06 ±	.00
2	25.0	2	S	.05	.01	E	.04	.02	S	.06	.00	E	.04	.01
3	25.0	20	S	.07	.01	S	.06	.01	S	.07	.02	S	.05	.02
4	25.0	20	S	.06	.02	E	.07	.01	S	.07	.03	E	.07	.01
5	25.0	200	S	.06	.01	S	.04	.01	S	.06	.01	S	.06	.03
6	25.0	200	S	.07	.02	E	.05	.01	S	.05	.01	E	.05	.00

PD = Power density in mW/cm^2
a = Week 1, three observations.
b = Week 2, three observations.
c = Week 3, three observations.
d = Week 4, three observations.
S = Sham treatment.
E = Exposure treatment.
$\overline{X}$ = Mean for the week.
SD = Standard deviation of the mean.

TABLE A4.6-5

MEAN ± STANDARD DEVIATION FOR SEARCH EFFICIENCY (NO. OF PREY/SEARCH TIME) FOR MULTIPLE ACUTE EXPOSURES AT 0.1, 10.0 AND 25.0 mW/cm^2

Bird No.	PD	Time Expo.	a	$\bar{X}$ ± SD	b	$\bar{X}$ ± SD	c	$\bar{X}$ ± SD	d	$\bar{X}$ ± SD
1	0.1	2	S	.01 ± .01	S	.03 ± .02	S	.04 ± .01	S	.02 ± .01
2	0.1	2	S	.03 .01	E	.04 .02	S	.04 .03	E	.02 .01
3	0.1	20	S	.06 .02	S	.03 .01	S	.04 .01	S	.02 .00
4	0.1	20	S	.06 .01	E	.05 .01	S	.05 .02	E	.02 .01
5	0.1	200	S	.04 .00	S	.04 .01	S	.07 .02	S	.03 .01
6	0.1	200	S	.05 .02	E	.04 .01	S	.03 .01	E	.03 .01
1	10.0	2	S	.10 ± .01	S	.04 ± .01	S	.06 ± .02	S	.05 ± .02
2	10.0	2	S	.10 .03	E	.08 .02	S	.07 .02	E	.06 .02
3	10.0	20	S	.05 .03	S	.05 .01	S	.03 .02	S	.09 .03
4	10.0	20	S	.06 .02	E	.05 .01	S	.09 .05	E	.10 .02
5	10.0	200	S	.09 .03	S	.08 .03	S	.10 .03	S	.10 .01
6	10.0	200	S	.07 .00	E	.05 .02	S	.05 .02	E	.06 .01
1	25.0	2	S	.09 ± .04	S	.09 ± .04	S	.06 ± .02	S	.09 ± .01
2	25.0	2	S	.06 .02	E	.07 .04	S	.09 .00	E	.06 .03
3	25.0	20	S	.10 .02	S	.09 .03	S	.10 .04	S	.07 .04
4	25.0	20	S	.10 .04	E	.12 .03	S	.12 .08	E	.11 .05
5	25.0	200	S	.11 .01	S	.12 .05	S	.10 .02	S	.11 .05
6	25.0	200	S	.13 .04	E	.08 .02	S	.07 .02	E	.10 .01

PD = Power density in mW/cm^2
a = Week 1, three observations.
b = Week 2, three observations.
c = Week 3, three observations.
d = Week 4, three observations.
S = Sham treatment.
E = Exposure treatment.
$\bar{X}$ = Mean for the week.
SD = Standard deviation of the mean.

TABLE A4.6-6

MEAN ± STANDARD DEVIATION FOR NONFORAGING TIME FOR MULTIPLE ACUTE EXPOSURES AT 0.1, 10.0 AND 25.0 mW/cm^2

Bird No.	PD	Time Expo.	a	$\bar{X}$ ±	SD	b	$\bar{X}$ ±	SD	c	$\bar{X}$ ±	SD	d	$\bar{X}$ ±	SD
1	0.1	2	S	728 ±	81	S	636 ±	110	S	691 ±	84	S	701 ±	20
2	0.1	2	S	731	34	E	616	106	S	697	97	E	618	146
3	0.1	20	S	750	102	S	714	66	S	745	30	S	717	69
4	0.1	20	S	797	58	E	717	57	S	746	84	E	751	72
5	0.1	200	S	707	29	S	675	30	S	724	59	S	613	133
6	0.1	200	S	643	78	E	649	81	S	714	50	E	648	138
1	10.0	2	S	751 ±	17	S	699 ±	99	S	793 ±	60	S	798 ±	70
2	10.0	2	S	755	3	E	763	52	S	772	58	E	791	15
3	10.0	20	S	668	204	S	742	62	S	767	102	S	829	44
4	10.0	20	S	775	28	E	763	13	S	807	42	E	791	23
5	10.0	200	S	773	34	S	712	31	S	783	29	S	751	39
6	10.0	200	S	683	21	E	677	98	S	715	96	E	743	85
1	25.0	2	S	480 ±	11	S	837 ±	8	S	721 ±	9	S	799 ±	24
2	25.0	2	S	797	6	E	775	84	S	819	20	E	820	21
3	25.0	20	S	857	16	S	809	24	S	793	22	S	797	20
4	25.0	20	S	791	29	E	801	13	S	809	38	E	820	36
5	25.0	200	S	755	73	S	707	46	S	790	22	S	748	84
6	25.0	200	S	795	16	E	757	50	S	739	49	E	825	8

PD = Power density in mW/cm^2.
a = Week 1, three observations.
b = Week 2, three observations.
c = Week 3, three observations.
d = Week 4, three observations.
S = Sham treatment.
E = Exposure treatment.
$\bar{X}$ = Mean for the week.
SD = Standard deviation of the mean.

TABLE A4.6-7A

MEAN + STANDARD DEVIATION FOR VARIABLES MEASURED DURING PRE-EXPOSURE, EXPOSURE AND POST-EXPOSURE PERIODS DURING SEVEN-DAY CONTINUOUS EXPOSURE TO POWER DENSITIES OF 0.0, 0.1, 1.0, 10.0 AND 25.0 mW/cm^2

BIRD NUMBER 12 POWER DENSITY 0.0 mW/cm^2

Variable		Pre-exposure			Exposure			Post-exposure	
List	N	$\overline{X}$	± SD	N	$\overline{X}$	± SD	N	$\overline{X}$	± SD
RTt	3	22.8	± 0.5	3	20.9	± 0.3	3	20.7	± 1.4
RTv	3	22.1	1.1	3	21.9	0.9	3	21.1	1.3
RTy	3	21.2	0.6	3	21.6	1.0	3	20.9	1.4
CTv	3	20.6	0.4	3	21.8	1.3	3	20.9	1.8
CTy	3	20.9	0.5	3	21.1	1.4	3	20.5	1.9
Hum.	3	39.0	2.1	3	41.3	5.5	3	37.0	4.6
NPrey	3	1.0	1.0	3	5.3	2.1	3	5.0	2.6
Th	3	3.3	3.1	3	22.0	10.6	3	24.0	15.1
Ts	3	98.7	61.8	3	81.3	45.0	3	103.3	60.1
Tnf	3	798.0	64.8	3	796.7	55.5	3	772.7	74.0
PROF	3	0.01	0.01	3	0.06	0.01	3	0.04	0.01
SRCH	3	0.01	0.01	3	0.07	0.02	3	0.05	0.01
DEPT	3	240.0	49.2	3	281.7	49.1	3	89.7	42.1
mass	2	29.6	0.9	1	30.8	0.0	1	29.8	0.0
other	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0
Thermbeh.	3	0.0	0.0	3	0.0	0.0	3	2.7	4.6

N = Number of observations in the period
$\overline{X}$ = Mean of measurements for that variable
SD = Standard deviation of the mean
RT = Room temperature
CT = Chamber temperature
v = Temperature as measured in volts by a Narda probe
y = Temperature as measured in °C by a YSI probe interfaced with a Hewlett-Packard data logger
Th = Handling time
Ts = Search time
Tnf = Nonforaging time
PROF = Profitability
SRCH = Search efficiency
DEPT = Deprivement time
other = Unrelated behavior
Thermbeh. = Thermoregulatory

TABLE 4.6-7B

MEAN ± STANDARD DEVIATION FOR VARIABLES MEASURED DURING PRE-EXPOSURE, EXPOSURE AND POST-EXPOSURE PERIODS DURING SEVEN-DAY CONTINUOUS EXPOSURE TO POWER DENSITIES OF 0.0, 0.1, 1.0, 10.0 AND 25.0 mW/cm^2

BIRD NUMBER 16   POWER DENSITY 0.0 mW/cm^2

Variable List	N	Pre-exposure $\bar{Y}$	± SD	N	Exposure $\bar{X}$	± SD	N	Post-exposure $\bar{Y}$	± SD
RTt	3	20.9	± 0.3	3	21.7	± 1.4	3	20.9	± 1.2
RTv	3	22.0	1.5	3	22.1	0.8	3	21.2	1.5
RTy	3	21.0	1.2	3	21.7	0.9	3	20.8	1.6
CTv	3	20.8	1.0	3	22.0	1.2	3	21.5	1.2
CTy	3	21.1	0.9	3	21.2	1.2	3	21.0	1.1
Hum.	3	45.3	4.5	3	41.3	5.5	3	36.0	4.0
NPrey	3	4.3	0.6	3	6.7	1.2	3	4.3	2.1
Th	3	20.7	2.3	3	37.3	9.4	3	34.7	17.2
Ts	3	139.3	22.3	3	69.3	11.0	3	77.3	29.1
Tnf	3	740.0	24.6	3	793.3	16.3	3	788.0	17.1
PROF	3	0.03	0.0	3	0.06	0.02	3	0.04	0.02
SRCH	3	0.03	0.0	3	0.10	0.03	3	0.07	0.06
DEPT	3	136.7	35.5	3	250.0	47.7	3	196.7	130.8
mass	2	27.8	1.1	1	28.5	0.0	1	25.5	0.0
other	3	0.0	0.0	3	0.0	0.0	3	0.7	1.1
Thermbeh.	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0

N = Number of observations in the period
$\bar{X}$ = Mean of measurements for that variable
SD = Standard deviation of the mean
RT = Room temperature
CT = Chamber temperature
v = Temperature as measured in volts by a Narda probe
y = Temperature as measured in °C by a YSI probe interfaced with a Hewlett-Packard data logger
Th = Handling time
Ts = Search time
Tnf = Nonforaging time
PROF = Profitability
SRCH = Search efficiency
DEPT = Deprivement time
other = Unrelated behavior
Thermbeh. = Thermoregulatory

TABLE A4.6-8A

MEAN ± STANDARD DEVIATION FOR VARIABLES MEASURED DURING PRE-EXPOSURE, EXPOSURE AND POST-EXPOSURE PERIODS DURING SEVEN DAY CONTINUOUS EXPOSURE TO POWER DENSITIES OF 0.0, 0.1, 1.0, 10.0 AND 25.0 mW/cm^2

BIRD NUMBER 11 POWER DENSITY 0.1 mW/cm^2

Variable		Pre-exposure			Exposure			Post-exposure	
List	N	$\bar{X}$ ±	SD	N	$\bar{X}$ ±	SD	N	$\bar{X}$ ±	SD
RTt (°C)	3	22.0 ±	0.9	3	21.1 ±	0.5	3	20.9 ±	1.1
RTv (°C)	3	21.8	1.6	3	21.6	0.2	3	21.1	0.8
RTy (°C)	3	20.9	1.0	3	21.4	1.0	3	20.8	1.0
CTv (°C)	3	20.3	0.7	3	21.0	0.8	3	21.2	1.6
CTy (°C)	3	20.8	0.7	3	41.3	0.9	3	20.5	1.2
Hum.(%)	3	39.3	2.1	3	6.3	5.5	3	37.3	5.1
NPrey-eater	3	9.7	0.6	3	42.6	1.5	3	6.7	0.6
Th (sec)	3	52.7	9.2	3	165.3	6.4	3	43.3	2.3
Ts (sec)	3	261.3	31.8	3	692.0	63.1	3	134.7	52.2
Tnf (sec)	3	587.3	37.8	3	0.03	58.9	3	722.0	50.5
PROF	3	0.03	0.0	3	0.04	0.01	3	0.04	0.01
SRCH	3	0.04	0.0	3	263.3	0.02	3	0.05	0.02
DEPT (sec)	3	198.3	103.0	3	25.3	173.3	3	195.0	96.6
mass (g)	2	26.0	0.03	1	0.0	0.0	1	24.5	0.0
other	3	4.0	6.9	3	0.0	0.0	3	0.0	0.0
Thermbeh.	3	0.0	0.0	3		0.0	3	0.0	0.0

N = Number of observations in the period
$\bar{X}$ = Mean of measurements for that variable
SD = Standard deviation of the mean
RT = Room temperature
CT = Chamber temperature
v = Temperature as measured in volts by a Narda probe
y = Temperature as measured in °C by a YSI probe interfaced with a Hewlett-Packard data logger
Th = Handling time
Ts = Search time
Tnf = Nonforaging time
PROF = Profitability
SRCH = Search efficiency
DEPT = Deprivement time
other = Unrelated behavior
Thermbeh. = Thermoregulatory

TABLE A4.6-8A (Continued)

MEAN ± STANDARD DEVIATION FOR VARIABLES MEASURED DURING PRE-EXPOSURE, EXPOSURE AND POST-EXPOSURE PERIODS DURING SEVEN DAY CONTINUOUS EXPOSURE TO POWER DENSITIES OF 0.0, 0.1, 1.0, 10.0 AND 25.0 mW/cm^2

BIRD NUMBER 14 POWER DENSITY 1.0 mW/cm^2

Variable		Pre-exposure			Exposure			Post-exposure	
List	N	$\overline{X}$ ± SD		N	$\overline{X}$ ± SD			$\overline{X}$ ± SD	
RTt	3	21.7 ±	2.0	3	20.9 ±	0.6	3	20.9 ±	0.6
RTv	3	21.8	1.3	3	21.1	0.8	3	21.2	0.7
RTy	3	20.7	1.0	3	20.8	1.0	3	21.0	0.9
CTv	3	20.2	0.5	3	21.4	0.9	3	21.3	1.5
CTy	3	20.6	0.5	3	20.7	1.1	3	20.6	0.9
Hum.	3	39.7	1.5	3	42.7	6.8	3	37.3	6.1
NPrey	3	9.0	1.7	3	9.0	1.0	3	9.7	1.5
Th	3	33.3	9.4	3	50.0	6.0	3	52.7	2.3
Ts	3	107.3	35.9	3	86.7	18.6	3	137.3	14.2
Tnf	3	759.3	45.4	3	763.3	23.7	3	710.0	14.0
PROF	3	0.07	0.01	3	0.07	0.01	3	0.05	0.01
SRCH	3	0.09	0.01	3	0.11	0.02	3	0.07	0.02
DEPT	3	225.0	158.7	3	178.3	133.3	3	230.0	82.6
mass	2	31.2	0.5	1	31.1	0.0	1	29.2	0.0
other	3	0.0	0.0	3	1.3	2.3	3	0.0	0.0
Thermbeh.	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0

N = Number of observations in the period
$\overline{X}$ = Mean of measurements for that variable
SD = Standard deviation of the mean
RT = Room temperature
CT = Chamber temperature
v = Temperature as measured in volts by a Narda probe
y = Temperature as measured in °C by a YSI probe interfaced with a Hewlett-Packard data logger
Th = Handling time
Ts = Search time
Tnf = Nonforaging time
PROF = Profitability
SRCH = Search efficiency
DEPT = Deprivement time
other = Unrelated behavior
Thermbeh. = Thermoregulatory

TABLE A4.6-9

SEVEN DAY CONTINUOUS EXPOSURE

Experiment #1

Bird #13   Power density = 10 mW/cm^2

Variable List	Pre-exposure N	Pre-exposure Mean	Pre-exposure SD	Exposure N	Exposure Mean	Exposure SD	Post-exposure N	Post-exposure Mean	Post-exposure SD
RTt	3	21.8	2.1	3	21.1	0.5	3	21.2	0.8
RTv	3	22.3	1.2	3	22.2	0.5	3	22.2	2.3
RTy	3	21.2	1.1	3	21.9	0.6	3	21.0	0.8
CTv	3	20.5	1.0	3	23.0	1.8	3	21.2	1.2
CTy	3	20.9	1.1	3	21.7	0.7	3	20.4	0.7
Humidity	3	40.0	3.0	3	42.7	5.9	3	37.3	6.1
N Prey	3	5.7	2.5	3	5.7	1.1	3	5.3	0.6
Th	3	26.7	20.1	3	31.3	8.1	3	22.0	0.0
Ts	3	124.0	62.5	3	102.7	21.0	3	100.7	48.4
Tnf	3	749.3	80.9	3	766.0	29.0	3	777.3	48.4
PROF2	3	.0395	.0140	3	.0426	.0047	3	.0465	.0118
SRCH2	3	.0483	.0204	3	.0555	.0061	3	.0589	.0189
DEPT	3	220.0	136.1	3	118.3	53.0	3	293.3	55.1
MASS	2	26.3	0.2	1	26.4	0.0	1	24.7	0.0
Other	3	2.0	3.5	3	0.0	0.0	3	0.0	0.0
Therm	3	0.7	1.1	3	0.0	0.0	3	0.0	0.0

TABLE A4.6-10

SEVEN-DAY CONTINUOUS EXPOSURE

Experiment #1

Bird #15 Power Density = 25 mW/cm^2

Variable List		Period							
		Pre-exposure			Exposure			Post-exposure	
		Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	20.8	0.3	3	21.3	0.6	3	21.0	0.8
RTv	3	21.3	1.8	3	22.3	0.9	3	21.1	0.6
RTy	3	20.3	1.5	3	21.7	0.6	3	20.9	0.8
CTv	3	20.4	1.0	3	23.8	1.0	3	21.5	0.8
CTy	3	20.7	1.0	3	23.7	1.2	3	20.8	0.7
Humidity	3	45.3	4.5	3	42.0	6.1	3	36.0	2.0
N Prey	3	1.0	1.7	3	2.7	2.3	3	3.7	1.5
Th	3	2.0	3.5	3	23.3	22.1	3	32.0	28.8
Ts	3	10.7	18.5	3	23.3	25.1	3	73.3	43.2
Tnf	3	887.3	21.9	3	852.0	49.0	3	794.7	60.1
PROF2	3	.0263	.0456	3	.0432	.0435	3	.0399	.0139
SRCH2	3	.0313	.0542	3	.0933	.1007	3	.0569	.0192
DEPT	3	86.7	7.6	3	175.0	56.3	3	200.0	131.1
MASS	2	26.8	0.8	1	27.5	0.0	1	25.0	0.0
Other	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0
Therm	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0

TABLE A4.6-11

REPLICATE #1 SEVEN-DAY CONTINUOUS EXPOSURE

Bird #21 Power Density = 0 mW/cm^2

Variable List	Period								
	Pre-exposure			Exposure			Post-exposure		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	19.8	0.3	3	19.1	1.1	3	18.5	0.2
RTv	3	20.6	1.1	3	20.6	0.9	3	20.4	0.9
RTy	3	19.7	1.6	3	20.1	0.8	3	20.3	0.5
CTv	3	19.9	0.9	3	20.5	0.7	3	20.7	0.6
CTy	3	19.8	0.8	3	20.3	0.6	3	20.4	0.5
Humidity	3	51.0	8.7	3	52.7	12.9	3	45.3	0.6
N Prey	3	8.0	2.6	3	7.3	0.6	3	6.0	1.7
Tn	3	96.7	50.8	3	116.7	76.0	3	44.0	15.6
Ts	3	78.7	26.1	3	106.7	16.0	3	73.3	16.8
Tnf	3	724.7	73.7	3	676.7	84.7	3	782.7	29.0
PROF	3	.0475	.0079	3	.0354	.0107	3	.0509	.0074
SRCH	3	.1030	.0250	3	.0694	.0073	3	.0809	.0060
DEPT	3	143.3	23.6	3	150.0	15.0	3	160.0	8.7
MASS	3	25.9	0.1	3	26.0	0.0	3	27.0	0.0
Other	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0
Therm	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0

TABLE A4.6-12

REPLICATE #1 SEVEN-DAY CONTINUOUS EXPOSURE

Bird #22 Power Density = 0.1 mW/cm^2

Variable List	Period								
	Pre-exposure			Exposure			Post-exposure		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	19.6	0.3	3	19.1	1.1	3	18.4	0.0
RTv	3	20.3	1.6	3	19.7	0.4	3	19.9	1.0
RTy	3	19.9	1.7	3	19.3	0.3	3	19.9	0.3
CTv	3	20.1	1.1	3	19.7	0.8	3	19.8	0.7
CTy	3	19.9	1.1	3	19.8	0.8	3	19.8	0.5
Humidity	3	50.7	9.0	3	57.7	15.3	3	45.3	0.6
N Prey	3	8.3	2.1	3	10.0	1.7	3	8.0	1.0
Th	3	53.3	1.5	3	68.0	18.0	3	62.0	22.5
Ts	3	118.7	50.6	3	116.0	47.0	3	108.7	14.2
Tnf	3	728.0	58.9	3	716.0	48.5	3	729.3	36.0
PROF	3	.0500	.0124	3	.0555	.0093	3	.0474	.0048
SRCH	3	.0764	.313	3	.0936	.0339	3	.0737	.0016
DEPT	3	140.0	22.9	3	155.0	34.6	3	160.0	8.7
MASS	2	28.2	4.3	1	25.4	0.0	1	25.1	0.0
Other	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0
Therm	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0

TABLE A4.6-13

REPLICATE NO. 1 SEVEN-DAY CONTINUOUS EXPOSURE

Bird #23 Power Density = 0.1 mW/cm^2

Variable List	Period								
	Pre-exposure			Exposure			Post-exposure		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	19.8	0.3	3	19.4	0.6	3	18.7	0.2
RTv	3	20.4	1.2	3	19.6	0.5	3	20.3	1.0
RTy	3	19.8	1.1	3	19.2	0.5	3	20.2	0.5
CTv	3	20.1	1.0	3	19.3	0.7	3	20.4	0.5
CTy	3	20.0	1.1	3	20.1	1.2	3	20.1	0.6
Humidity	3	51.0	8.7	3	56.0	14.0	3	45.3	0.6
N Prey	3	5.0	2.6	3	7.3	1.2	3	5.3	1.5
Th	3	33.3	18.6	3	50.0	14.0	3	31.3	1.2
Ts	3	50.0	22.5	3	120.7	7.6	3	62.0	45.4
Tnf	3	816.0	36.3	3	729.3	6.4	3	806.7	44.3
PROF	3	.0581	.0185	3	.0429	.0060	3	.0602	.0102
SRCH	3	.1038	.0579	3	.0612	.0122	3	.1046	.0381
DEPT	3	141.7	20.8	3	185.0	45.8	3	151.7	2.9
MASS	1	24.6	0.5	1	25.2	--	1	25.0	--
Other	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0
Therm	3	0.0	0.0	3	0.0	0.0	3	0.0	0.0

TABLE A4.6-14

REPLICATE NO. 1 SEVEN-DAY CONTINUOUS EXPOSURF

Bird #24 Power Density = 10 mW/cm^2

Variable List	Period								
	Pre-exposure			Exposure			Post-exposure		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	19.8	0.4	3	19.2	0.9	3	18.8	0.0
RTv	3	21.1	0.9	3	20.1	0.8	3	20.9	0.3
RTy	3	20.5	0.9	3	19.6	0.9	3	20.6	0.2
CTv	3	20.1	1.3	3	21.2	0.9	3	21.0	0.4
CTy	3	19.8	0.8	3	20.3	0.6	3	20.4	0.5
Humidity	3	51.0	8.7	3	52.0	13.7	3	45.3	0.6
N Prey	3	4.3	1.1	3	2.0	1.0	3	5.7	0.6
Th	3	25.3	13.3	3	8.7	7.0	3	25.3	5.0
Ts	3	46.7	9.4	3	30.7	36.3	3	50.0	5.3
Tnf	3	828.0	22.7	3	860.7	37.5	3	824.7	2.2
PROF	3	.0610	.0042	3	.0952	.0709	3	.0752	.0069
SRCH	3	.0920	.0084	3	.1551	.1146	3	.1148	.0219
DEPT	3	145.0	17.3	3	175.0	37.7	3	170.0	8.7
MASS	2	27.0	0.7	1	29.3	—	1	28.7	--
Other	3	0	0	3	0	0	3	0	0
Therm	3	0	0	3	0	0	3	0	0

TABLE A4.6-15

REPLICATE NO. 1 SEVEN-DAY CONTINUOUS EXPOSURE

Bird #25 Power Density = 25 mW/cm^2

Variable List	Period								
	Pre-exposure			Exposure			Post-exposure		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	19.8	0.3	3	19.2	0.9	3	18.7	0.2
RTv	3	21.2	0.8	3	19.5	1.4	3	20.4	0.7
RTy	3	20.7	1.2	3	18.9	1.2	3	20.3	0.6
CTv	3	19.9	1.4	3	24.2	1.6	3	20.7	0.7
CTy	3	19.9	1.1	3	19.8	0.8	3	19.8	0.5
Humidity	3	51.0	8.7	3	52.7	12.9	3	45.0	1.0
N Prey	3	6.0	1.0	3	9.3	1.5	3	7.7	3.2
Th	3	37.3	17.9	3	88.7	21.2	3	44.0	7.2
Ts	3	82.7	31.0	3	151.3	17.9	3	70.7	30.7
Tnf	3	780.0	48.9	3	717.3	101.3	3	785.3	36.7
PROF	3	.0530	.0116	3	.0390	.0071	3	.0657	.0067
SRCH	3	.0761	.0146	3	.0628	.0156	3	.1096	.0135
DEPT	3	140.0	22.9	3	133.3	7.6	3	153.3	2.9
MASS	2	26.2	3.1	1	29.1	--	1	28.1	--
Other	3	0	0	3	4.7	8.1	3	0	0
Therm	3	0	0	3	0	0	3	0	0

TABLE A4.6-16

REPLICATE NO. 1 SEVEN-DAY CONTINUOUS EXPOSURE

Bird #26 Power Density = 0

Variable List	Period								
	Pre-exposure			Exposure			Post-exposure		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
RTt	3	19.3	1.4	3	19.6	0.3	3	18.5	0.2
RTv	3	21.4	0.7	3	20.2	0.5	3	20.0	0.9
RTy	3	21.0	1.1	3	19.7	0.5	3	20.1	0.2
CTv	3	19.8	1.4	3	20.4	1.2	3	20.3	0.5
CTy	3	20.0	1.0	3	19.6	0.4	3	20.2	0.2
Humidity	3	58.3	10.3	3	43.7	4.6	3	45.7	0.6
N Prey	3	4.7	1.5	3	4.3	1.5	3	5.0	1.0
Th	3	28.0	6.9	3	19.3	4.2	3	50.7	26.6
Ts	3	98.7	27.7	3	84.0	22.0	3	71.3	30.6
Tnf	3	773.3	30.1	3	796.7	20.0	3	778.0	15.9
PROF	3	.0363	.0044	3	.0423	0.0115	3	.0416	.0102
SRCH	3	.0468	.0026	3	.0523	0.0149	3	.1820	.0437
DEPT	3	135.0	0.0	3	150.0	0.0	3	155.0	8.7
MASS	2	28.9	0.3	1	27.6	—	1	26.4	--
Other	3	0	0	3	0	0	3	0	0
Therm	3	0	0	3	0	0	3	0	0

TABLE A4.6-17

MEAN (STANDARD DEVIATION) FOR ENVIRONMENTAL AND FORAGING VARIABLES FOR FOUR WEEK CONTINUOUS EXPOSURE AT 0.0 AND 25.0 mW/cm^2

(For abbreviations see Appendices 7 and 8)

	Pre-exposure		Exposure		Post-exposure	
Variable	0 mW/cm^2	25 mW/cm^2	0 mW/cm^2	25 mW/cm^2	0 mW/cm^2	25 mW/cm^2
RTT°C	19.4 (0.8)	19.8 (0.7)	19.8 (1.0)	19.8 (1.3)	20.5 (1.8)	20.2 (2.0)
RTY°C	15.3 (1.9)	15.4 (2.2)	17.3 (1.8)	17.9 (1.5)	18.2 (2.8)	19.1 (2.2)
RTN°C	15.1 (1.6)	15.5 (1.8)	17.0 (1.7)	17.6 (1.6)	19.0 (2.4)	19.5 (2.0)
CTY°C	15.7 (3.1)	16.5 (3.1)	18.4 (2.3)	19.2 (1.9)	17.4 (1.3)	18.1 (1.5)
CTN°C	15.8 (3.9)	16.7 (4.3)	18.6 (2.9)	19.8 (2.4)	19.2 (2.4)	19.8 (2.3)
HUMID	43 (12)	50 (9)	53 (10)	63 (10)	47 (16)	54 (14)
N PREY	5.4 (1.9)	4.2 (1.8)	4.4 (2.0)	4.8 (2.1)	4.1 (1.7)	4.2 (1.8)
TS (sec)	89 (37)	69 (40)	66 (39)	69 (38)	47 (32)	73 (42)
TH (sec)	58 (26)	55 (28)	37 (21)	44 (26)	37 (21)	38 (28)
TNF (sec)	753 (45)	748 (50)	797 (54)	786 (55)	822 (41)	789 (65)
PROF2	0.04 (.01)	0.04 (.01)	0.04 (.02)	0.05 (.02)	0.05 (.02)	0.04 (.02)
SRCH2	0.07 (.03)	0.08 (.07)	0.07 (.04)	0.08 (.04)	0.10 (.06)	0.07 (.03)
DEPTIME (min)	138 (24)	144 (19)	151 (22)	149 (22)	156 (9)	135 (20)
Mass (g)	27.7 (2.0)	28.0 (2.8)	27.3 (2.5)	27.5 (3.3)	27.3 (3.5)	27.8 (2.6)
OTHER	0	11 (34)	0	11 (64)	0	0 (1)
THERMBEH	0	0	0	0	23 (84)	0

TABLE A4.7-1

DATA ON COMPLETED CLUTCHES OF TAENIOPYGIA GUTTATA

Group 1 -- Control

Pair	Clutch	Eggs	Fertile Eggs	Hatching Eggs	Fledglings	Number of Days Between Clutches n and n-1
1	1	6	0	0	0	--
	2	6	2	2	0	9
	3	5	3	3	0	32
	4	6	5	4	4	23
	5	6	5	4	2	45
2	1	4	0	0	0	--
	2	7	4	0	0	8
	3	6	1	0	0	10
	4	5	0	0	0	9
	5	8	0	0	0	7
	6	4	4	2	0	29
	7	5	4	4	4	20
3	1	5	4	1	0	--
	2	5	3	0	0	30
	3	5	5	4	4	16
	4	7	3	0	0	41
	5	6	5	5	4	12
Total	17	96	48	29	14	
Group 2 -- Experimental						
4	1	6	1	0	0	--
	2	4	4	3	2	14
	3	5	5	5	4	37
	4	4	4	2	2	71
5	1	5	2	0	0	--
	2	5	3	3	2	38
6	1	4	0	0	0	--
	2	6	0	0	0	10
	3	1	1	0	0	25
	4	8	0	0	0	19
	5	10	0	0	0	35
	6	6	1	0	0	28
Total	12	64	21	13	10	

TABLE A4.7-2

PAIR MEANS AND STANDARD DEVIATIONS FOR TIME BUDGETS OF *TAENIOPYGIA GUTTATA*. ACTIVITIES OF BOTH PAIR MEMBERS RECORDED AT 30 SECOND INTERVALS FOR 15 MINUTE OBSERVATION PERIODS, GIVING A TOTAL OF 60 BEHAVIORAL UNITS PER OBSERVATION SESSION. THERMOREGULATORY STATES RECORDED IN ADDITION TO THE PRIMARY ACTIVITY

	Control						Experimental					
Behavior	Pair 1		Pair 2		Pair 3		Pair 4		Pair 5		Pair 6	
Random activity	10.5 ±	7.68	24.8 ±	12.65	18.2 ±	31.38	20.7 ±	11.18	30.1 ±	14.07	21.4 ±	13.30
Maintenance	5.6	11.00	7.7	8.36	6.2	7.19	4.8	5.42	8.6	9.25	8.4	10.82
Feeding	8.9	5.86	9.4	7.00	11.0	21.07	9.8	8.41	6.6	5.61	4.6	3.61
Reproductive	35.3	11.46	17.6	12.50	28.9	14.26	23.9	16.15	14.5	15.43	25.5	16.06
Aggressive	0.2	0.51	0.4	.90	0.8	2.07	3.4	14.38	0.1	0.44	1.6	3.84
Thermoregulatory	0.1	0.36	0.0	0.00	0.0	0.00	4.0	6.82	1.0	3.85	1.6	3.84
n of observations	100		62		98		101		63		103	

APPENDIX A4.7-3

RATES OF TEMPERATURE RISE (L) OF COTURNIX QUAIL AND CHICKEN EGGS IRRADIATED BY 92 mW/cm^2 MICROWAVES

	Coturnix Quail		Chicken	
	Mass (g)	L (°C/min)	Mass (g)	L (°C/min)
	9.27	0.7711	61.43	0.4077
	9.44	0.8709	60.51	0.4423
	10.25	0.8675	59.76	0.4490
	10.04	0.7292	60.50	0.4399
	8.29	0.7337	60.74	0.4516
	10.10	0.8375	58.41	0.4504
	10.24	0.6202		
	9.48	0.8110		
	9.05	0.6020		
	10.03	0.5454		
	9.69	0.5694		
	10.06	0.6316		
	9.48	0.7489		
	9.90	0.6310		
	9.15	0.9333		
	9.92	0.8733		
n	16	16	6	6
$\bar{X}$	9.65	0.7360	60.23	0.4402
S.D.	0.53	0.1233	1.04	0.0166

APPENDIX A4.7-4

SPECIFIC HEATS (S) OF COTURNIX QUAIL AND CHICKEN EGGS

	Coturnix Quail		Chicken	
	Mass (g)	S (cal/g/°C)	Mass (g)	S (cal/g/°C)
	9.60	0.82	60.45	0.83
	11.13	0.93	58.83	0.79
	10.30	0.92	65.72	0.87
	9.85	0.88	65.65	0.83
			61.67	0.85
			60.54	0.86
			61.72	0.87
			58.86	0.86
			63.60	0.86
			66.97	0.79
			73.15	0.87
			64.58	0.79
			65.54	0.81
			63.61	0.81
			61.58	0.82
			63.66	0.81
n	4	4	16	16
$\bar{X}$	10.22	0.89	63.51	0.83
S.D.	0.67	0.05	3.57	0.03

APPENDIX A4.8-1

ONSET OF THERMOREGULATORY RESPONSES DURING AND AFTER FLIGHT

		Ambient Conditions[1]		Microwave Exposure	Onset of Thermoregulatory Responses during Flight			Onset of Stress Levels I - V after Flight					
Bird I.D.	Flight No.	T_a (°C)	P_a (torr)	(mW/cm^2)	Leg-Drop (seconds)	Gape (seconds)	Land[2] (seconds)	V (seconds)	IV (seconds)	III (seconds)	II (seconds)	I (seconds)	Recovery (seconds)
"-W"	1	31.7	17.81	0	40	-	-	-	-	-	-	10	200*
	2	27.8	17.48	50	40	330	-	-	-	-	-	10	170*
	3	28.9	19.21	0	450	-	-	-	-	-	10	250	280*
	4	30.4	20.61	50	40	220	-	-	10	20	80	260	330*
	5	29.2	19.21	0	90	200		-	-	-	10	30	100*
	6	31.5	20.29	50	10	20	340	-	10	20	70	260	330*
	7	34.6	21.87	0	-	-	-	-	-	-	10	170	300*
	8	35.1	27.61	50	260	-	-	-	10*	-	-	-	-
"O-"	1	31.4	15.99	0	-	-	-	-	10	70	210	320	360*
	2	32.7	19.43	50	110	150	470	-	10	440	580*	-	-
	3	31.2	20.61	0	380	-	-	-	-	10	190	300	350*
	4	28.1	18.88	50	210	260	-	-	10	90	220	290	350*
	5	34.1	21.87	0	280	300	-	-	10	340	560*	-	-
	6	35.1	21.87	50	60	110	340	10	440*	-	-	-	-
	7	28.2	17.86	0	470	-	-	-	10	70	170	260	370*
	8	30.8	20.29	50	110	200	390	10	240	330	490*	-	-
"WPG"	1	30.8	15.81	0	70	-	-	-	-	-	10	230	330*
	2	26.1	17.48	50	30	-	-	-	-	-	10	110	220*
	3	28.0	18.77	0	330	-	-	-	-	-	-	10	100*
	4	31.0	20.61	50	30	170	500	10*	-	-	-	-	-
	5	34.4	22.38	0	60	230	-	380	10*	-	-	-	-
	6	28.3	18.40	0	-	-	550	-	-	10	30	320	380*
	7	31.6	21.21	50	120	170	390	-	10	550*	-	-	-
"-O"	1	30.3	15.99	0	-	-	-	-	-	-	10	140	180*
	2	34.2	19.43	50	70	160	420	10	20	370*	-	-	-
	3	30.8	20.61	0	-	-	-	-	-	10	30	50	220*
	4	27.0	19.20	50	110	-	-	-	10	40	90	110	210*
	5	33.8	28.84	0	160	-	-	-	-	10	50	300	350*
	6	34.8	23.02	50	30	140	480	-	10*	-	-	-	-
	7	29.5	19.33	0	310	-	-	-	-	-	-	10*	-
	8	30.0	21.10	50	250	-	-	-	10	120	140	180	250*

[1] T_a is ambient temperature; P_a is the water vapor pressure.

[2] Budgerigar lands before 600 s flight is completed.

* Minimum stress level observed during 10 min recovery period.

(-) Response or stress level was not observed.

APPENDIX A4.8-2a

ONSET OF THERMOREGULATORY RESPONSES DURING FLIGHTS AND BODY TEMPERATURES MEASURED BEFORE AND AFTER FLIGHTS OF BUDGERIGARS: "-W", "O-", "G-", AND "-B"

		Ambient Conditions[1]		Microwave Exposure	Onset of Thermo-regulatory Responses during Flight			Body Temperature	
Bird I.D.	Flight No.	T_a	P_a		Leg-Drop	Gape	Land[2]	Pre-flight	Post-Flight
		(°C)	(torr)	(mW/cm^2)	(seconds)			(°C)	(°C)
"-W"	1	25.4	17.79	0	-	-	-	41.8	42.6
	2	28.7	17.50	50	370	410	-	42.2	42.9
	3	30.1	20.29	0	140	-	-	43.0	42.4
	4	29.8	16.53	50	60	130	-	42.2	43.4
	5	32.3	13.22	0	110	-	-	42.7	42.7
	6	28.1	9.92	50	210	550	-	42.8	42.9
	7	26.9	14.09	0	-	-	-	43.9	43.2
	8	27.6	12.84	50	-	-	-	42.7	42.5
	9	25.4	14.61	0	-	-	-	42.3	42.6
	10	26.9	13.52	50	260	-	-	42.0	42.5
	11	33.5	16.80	0	40	-	-	43.5	43.2
	12	30.9	16.19	50	60	100	-	43.5	43.5
	13	28.1	16.22	0	40	-	-	43.8	43.0
	14	27.8	16.22	50	40	-	-	42.8	42.5
	15	29.1	16.28	0	40	-	-	42.9	43.2
	16	29.2	16.28	50	50	450	-	43.6	43.0
"O-"	1	25.7	13.96	0	-	-	-	43.0	42.8
	2	27.3	14.45	50	160	460	-	42.1	43.2
	3	30.8	21.51	0	270	390	-	42.5	42.6
	4	29.2	17.37	50	170	220	540	42.2	43.5
	5	31.7	11.68	0	270	-	-	42.8	43.8
	6	27.0	12.00	50	350	540	-	42.5	43.4
	7	27.2	12.83	0	-	-	-	42.7	43.3
	8	26.2	13.40	50	170	590	-	43.2	43.4
	9	29.1	17.03	0	-	-	-	42.4	42.0
	10	28.4	17.48	50	-	-	-	43.1	43.0
"G-"	1	24.8	14.36	0	-	-	-	42.3	43.2
	2	26.8	13.52	50	170	-	-	41.5	43.4
	3	33.2	17.26	0	190	-	-	43.0	43.9
	4	31.9	16.60	50	50	190	-	41.9	44.8
"-B"	1	29.0	14.85	0	60	370	-	43.0	43.5
	2	29.3	14.85	50	90	110	350	43.0	43.7
	3	25.9	17.79	0	470	-	-	41.5	42.9
	4	29.9	16.99	50	70	180	-	42.1	44.5

[1] T_a is ambient temperature; P_a is the water vapor pressure.

[2] Budgerigar lands before 600 s flight is completed.

(-) Response was not observed.

APPENDIX A4.8-2b

ONSET OF THERMOREGULATORY RESPONSES DURING FLIGHTS AND BODY TEMPERATURES MEASURED BEFORE AND AFTER FLIGHTS OF BUDGERIGARS: "WPG" AND "-O"

		Ambient Conditions[1]		Microwave Exposure	Onset of Thermoregulatory Responses during Flight			Body Temperature	
Bird I.D.	Flight No.	T_a	P_a		Leg-Drop	Gape	Land[2]	Pre-Flight	Post-Flight
		(°C)	(torr)	(mW/cm^2)	(seconds)			(°C)	(°C)
"WPG"	1	24.7	15.82	0	-	-	-	42.0	42.7
	2	28.0	14.45	50	60	210	-	42.2	43.7
	3	21.6	19.68	0	130	260	-	42.9	42.8
	4	28.7	15.69	50	80	210	350	42.3	43.7
	5	31.6	12.61	0	160	370	-	43.6	43.6
	6	27.0	10.54	50	60	160	-	43.6	43.4
	7	27.0	12.15	0	150	-	-	42.6	43.1
	8	26.5	12.84	50	180	-	-	42.6	43.2
	9	24.5	13.94	0	-	-	-	42.9	43.2
	10	26.2	14.67	50	200	320	-	42.8	43.2
	11	33.4	16.80	0	170	-	-	43.4	43.6
	12	32.6	16.82	50	80	-	300	42.8	44.0
	13	27.6	16.49	0	280	-	-	43.8	43.5
	14	28.2	16.98	50	110	330	350	43.0	43.5
	15	29.2	17.10	0	-	-	-	42.4	43.1
	16	28.9	16.31	50	170	-	-	42.7	43.2
"-O"	1	24.4	15.82	0	-	-	-	41.8	43.0
	2	28.8	14.45	50	110	350	-	42.5	43.4
	3	26.1	17.79	0	-	-	-	41.5	41.9
	4	30.2	19.00	50		390	-	42.1	43.7
	5	31.6	12.46	0	240	-	-	42.8	43.1
	6	25.0	13.32	50	-	-	-	42.1	43.6
	7	27.3	15.20	0	-	-	-	42.8	42.4
	8	25.5	13.53	50	210	-	-	42.8	43.0
	9	24.2	15.25	0	-	-	-	41.9	42.5
	10	25.5	14.80	50	-	-	-	42.0	43.1
	11	32.9	22.07	0	250	-	-	43.1	43.8
	12	33.1	16.80	50	80	260	490	42.8	46.1
	13	27.3	20.92	0	600	-	-	43.6	43.1
	14	28.2	16.98	50	290	-	-	43.1	43.1
	15	29.4	17.10	0	-	-	-	42.4	42.9
	16	29.6	16.31	50	470	-	-	42.4	43.3

[1] T_a is ambient temperature; P_a is the water vapor pressure.

[2] Budgerigar lands before 600 s flight is completed.

(-) Response was not observed.

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